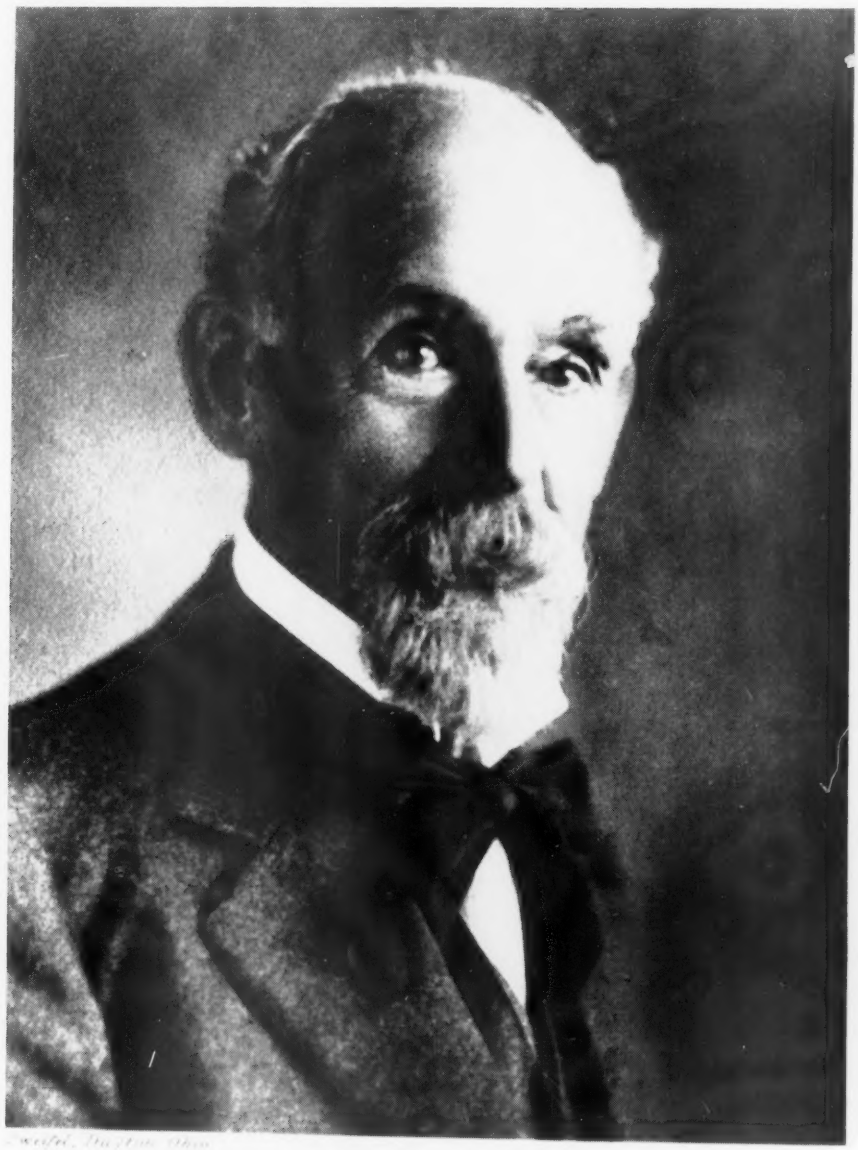
THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 19 NOVEMBER, 1940 Number 11



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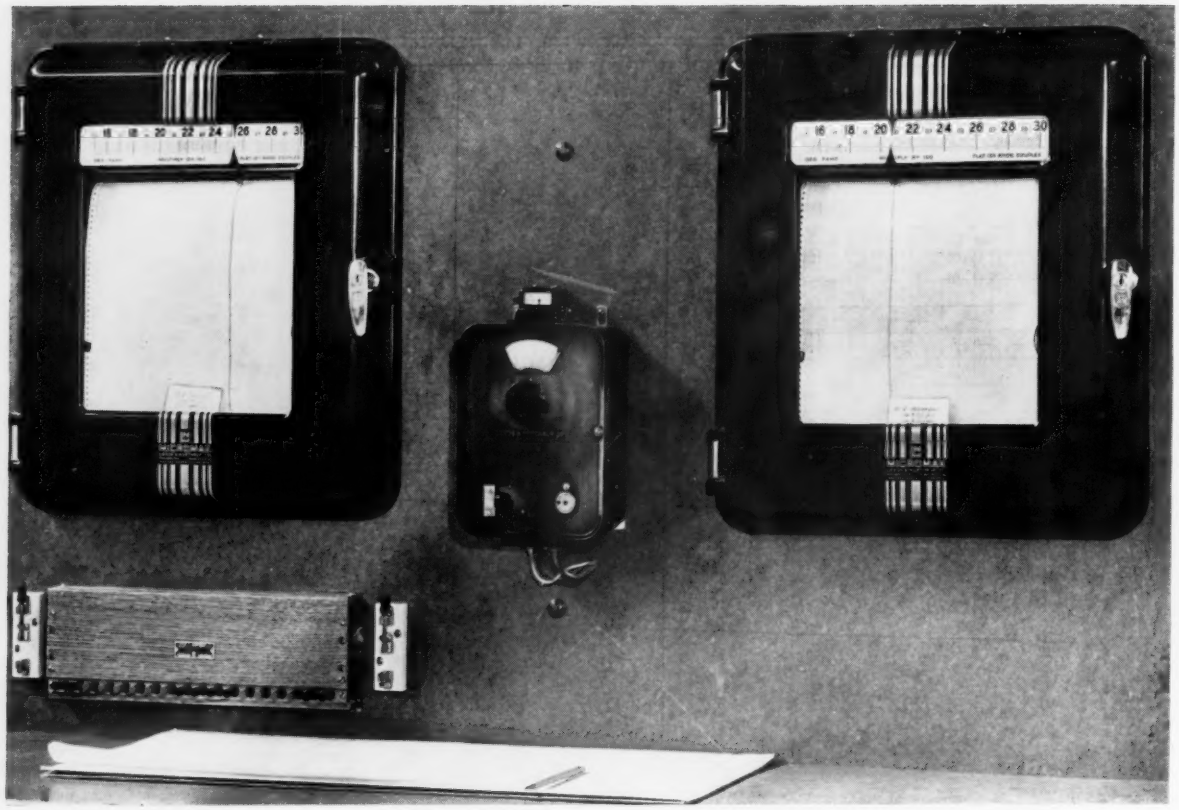
Ivor A. Brashear



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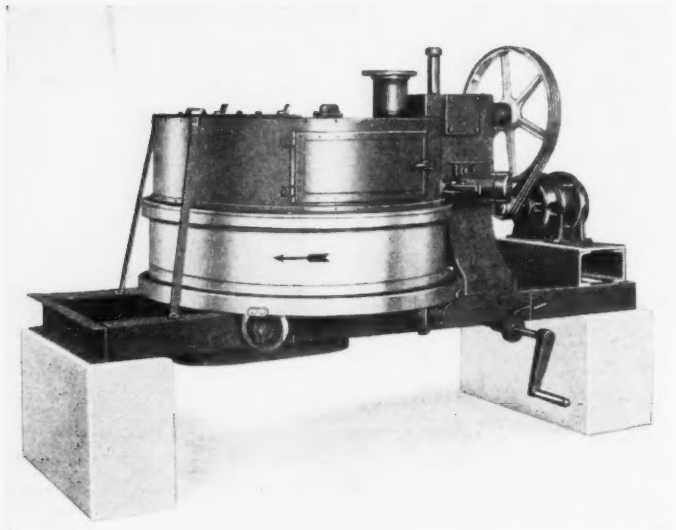

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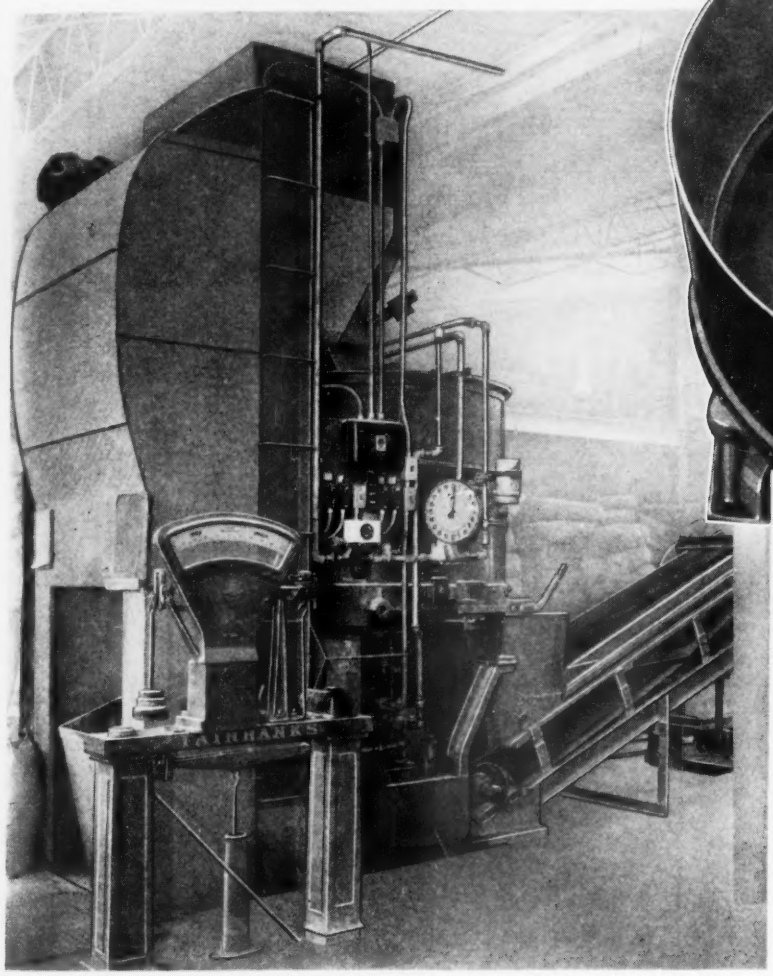

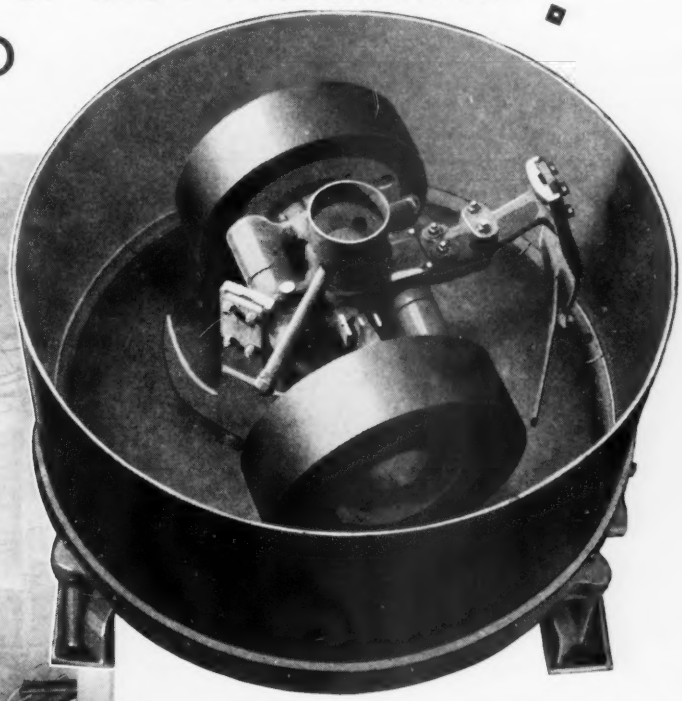

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Fire placed in tank	October 4, 1937
Production started	October 18, 1937
Production off—fires out	February 27, 1939
Fires placed back in tank	March 2, 1939
Production on	March 7, 1939
Production off—fires out	March 11, 1940
Melting end area	504 Square feet

Total days life	884
Operating days	833
Days heating up	17
Idle days	34

Total tons glass produced	65,011
Tons glass produced per operating day	78.0
Sq. ft. melting area per ton glass per operating day	6.46
Average pack	90%
Cause of shut down	Ports
Tons per sq. ft. melting area per life	128.9

Note: When this tank was rebuilt, Corhart* Standard Electrocast was used in breastwalls and ports.

This, you will agree is a rather spectacular record. Yet it has been closely approached by several Corhart tanks in the past, and will unquestionably be exceeded by many such tanks in the future. For the glass industry is moving forward more rapidly today than ever before, and the records of 1940 are unquestionably the commonplace performances of tomorrow. . . .

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A Monthly Publication Devoted to Proceedings of The Society and Promotion of Cooperative Research of Technical, Scientific, and Art Questions

Volume 19 **NOVEMBER, 1940** **Number 11**

PAPERS

PROPERTIES AND CHARACTERISTICS OF ENAMELING IRON*

By Joseph C. Eckel and John A. Eckel†

Abstract

The physical and chemical properties and microstructure of a continuous mill-enameled sheet steel are discussed as well as their relation to the enameling process. Heat treatment, mechanical working, and other phases of mill operations which tend to influence the performance of the sheet steel during enameling are also described.

I. Introduction

The object of this paper is to present some of the properties and characteristics of enameling sheets made by the continuous mill process and to show the effect that these factors exercise on the ultimate performance in the enameling shop.

The subject has been subdivided into (1) and (2) properties and characteristics of enameling iron, respectively, and (3) a summary of the effect of (1) and (2) on the performance in the enameling shop.

Enameling sheets are processed essentially from pure iron in which the elements usually associated with iron are held as low as possible. The steel generally is a basic open-hearth, rimming type having a typical analysis of carbon 0.03%, manganese 0.06%, phosphorus 0.008%, sulfur 0.020%, silicon 0.009%, and copper 0.04%.

The ingots are rolled into slabs (varying in size from 3 to 7.5 in. thick, 2 to 6 ft. wide, and 6 to 14 ft. long) and are sent to sheet mills for finishing into sheet form.

At the sheet mill, the slabs are heated to approximately 2300°F. for three to four hours in slab-heating furnaces to prepare them for rolling. When the slabs are thoroughly heated, they are discharged from the furnace to the continuous-strip mill run-out table and are passed through a series of four 4-high roughing stands onto an intermediate table and then through a series of six 4-high finishing mills. On its course through the strip mill, the slab will decrease markedly in thickness and increase in length. It emerges from the last stand as a long "ribbonlike" strip, approximately 800 to 1000 ft. in length, traveling at speeds up to 2100 ft. per minute. The run-out table conveys the strip to coilers which wind it into coils.

After hot-strip rolling, the material is permitted to cool for forty-eight hours before pickling. Dilute sulfuric-acid solutions, maintained at temperatures of 180° to 200°F., remove the strip-mill oxide as it is conveyed uncoiled through the continuous pickling units. As the strip is recoiled at the exit end of the pickler, it is oiled to protect the clean pickled surface from rust.

Coils from the line pickler are now ready for cold reduction, which is accomplished either on reversing mills or on tandem mills. Reversing mills are of the single-stand type and consist of two working rolls and two back-up rolls. Tandem mills generally consist of three single stands, all of the 4-high type. The general practice is to reduce the hot-strip material by 50 to 60% to the gauge ordered by the customer. As the strip emerges from the exit end, it is coiled at speeds of 500 to 800 ft. per minute.

The material is heat-treated as sheets after cold reduction. The coils from the cold reduction mills are sheared to sheets on "flying shears" at speeds approximating 500 ft. per minute.

The heat treatment generally used on enameling iron is known as normalizing, which consists of heat-treating the material at furnace temperatures of 1800° to 1850°F. for about one to two minutes. The purpose of the heat treatment is to remove the stresses imparted by cold reduction and to produce a uniform and equiaxial grain structure.

Some distortion of the material results from this heat treatment, and because flatness is important in

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 9, 1940 (Enamel Division). Received May 11, 1940.

† J. C. Eckel is with the Sheet Division of the Carnegie-Illinois Steel Corp., Pittsburgh, Pa.; J. A. Eckel is General Foreman of the Metallurgical Department, Gary Sheet Mill, Carnegie-Illinois Steel Corp., Gary, Ind.

an enameling sheet, the material must be processed further by skin or temper passing.

Before this operation, however, the scale formed on the sheets during the normalizing operation must be removed with 6 to 8% (by weight) of sulfuric acid at temperatures of 140° to 160°F.; the time of immersion in the acid is from ten to twenty minutes.

Skin-pass or temper mills are generally of the 4-high type. There is little increase in the length of the material rolled on these mills, and an exceptionally flat product is obtained. Special surfaces of varying degrees of roughness may be imparted to the material by special preparation of the working rolls.

The material is now ready for inspection before shipment.

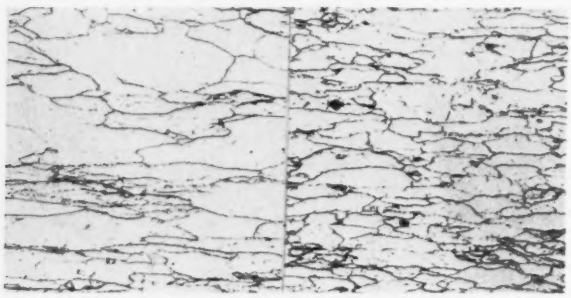

FIG. 1.—Enameling iron as hot strip: (*left*) surface of gauge; (*right*) center of gauge; 100 ×.

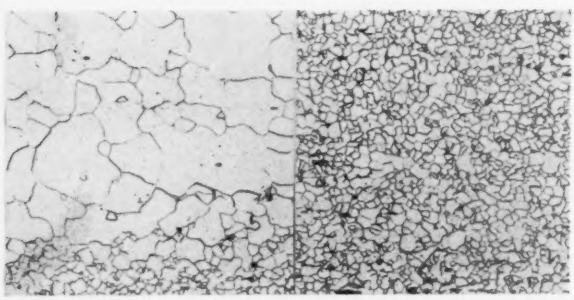

FIG. 2.—Typical structure of auto-body steel that may be finished at a high temperature: (*left*) surface of gauge; (*right*) center of gauge; 100 ×.

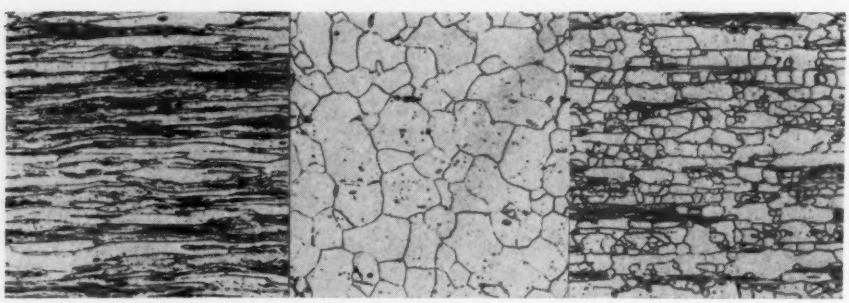

FIG. 3.—(*Left*) Grain distortion in direction of rolling; (*center*) uniform, equiaxial grain structure produced by normalizing treatment; (*right*) enameling iron processed by box annealing showing poor response to grain size; all 100 ×.

II. Properties

Because of its relatively low carbon and manganese content, enameling iron cannot be properly hot-rolled in the temperature range of 1650° to 1950°F., the "red-short" or "nonmalleable" range. Hot-working in this temperature range causes considerable edge-cracking of the strip. As it is impractical on a strip mill to roll above 1950°F., the general practice is to roll the strip through the roughing stands above this temperature and to hold it on the intermediate table before it enters the finishing train until it has cooled to a temperature below the lower limit of 1650°F. Strip-mill finishing temperatures on enameling iron for this reason will approximate 1460° to 1520°F. Figure 1 shows a photomicrograph of enameling iron as hot strip at 100 magnifications. This is in contrast to Fig. 2, which shows a typical structure of auto-body steel that may be finished at a higher temperature. Enameling iron as hot strip will show Rockwell B hardness values in the range of B45 to B65. Tensile values will approximate 30,000 to 45,000 lb. per sq. in. yield point, 45,000 to 55,000 lb. per sq. in. ultimate strength, and from 18 to 30% of elongation in 2 in.

After cold-reducing to the finished gauge, the material loses all semblance of ductility. Rockwell B hardness approximates B80 to B90, and a microsection of the material, Fig. 3 (*left*), shows considerable grain distortion in the direction of rolling. Tensile values will show 75,000 to 90,000 lb. per sq. in. of ultimate strength and 1 to 5% of elongation in 2 in. Because of the excessive cold reduction, the material in this stage of the processing will have no "drop-of-the-beam" yield point.

Normalizing imparts to enameling sheets grain structures and physical properties conducive to good drawing and enameling. Rockwell B hardnesses vary from B35 to B45; yield strength, 23,000 to 28,000 per sq. in.; ultimate strength, 40,000 to 45,000 lb. per sq. in.; and from 30 to 40% of elongation in 2 in. (the percentage of elongation is dependent on sheet thickness). Figure 3 (*center*) shows that normalizing produces a uniform, equiaxial grain structure. All trace of rolling direction has been eliminated by this heat treatment.

Box annealing, which involves soaking the material from 15 to 25 hours at 1200° to 1300°F. and furnace-cooling, has not been successful in the production of enameling iron. Because of its high purity, this iron does not respond readily to box-annealing temperatures. Metallurgically, enameling iron that is processed by box annealing will show poor response to grain size, Fig. 3 (*right*). Rockwell B hardnesses will vary from B50 to B60; yield points, from 27,000 to 36,000 lb. per sq. in.; ultimate strength, 42,000 to 50,000 lb. per sq. in.; and 25 to 35% of elongation in 2 in., depending on sheet thickness.

Temper- or skin-passing as a cold-rolling operation has little influence on the physical properties when tests are made immediately following this operation. No effect is observed on grain size and ultimate strength, the percentage of elongation in 2 in. is slightly decreased, and the Rockwell hardness and yield strength are increased slightly.

So much has appeared in the literature concerning age-hardening of mild steel that little need be said of enameling iron because the same general principles apply. When enameling iron is processed by cold rolling as a final operation, it will show aging with the passage of time; that is, there will be an increase in hardness and a decrease in ductility. After aging, enameling iron will show an increase of 4 to 8 points in Rockwell B hardness, 2000 to 5000 lb. per sq. in. in yield point, and a decrease of 2 to 4% elongation in 2 in.

If box annealing is employed after temper-passing to remove strains and to prevent subsequent age-hardening, the effect on the properties of the annealing, which generally consists of heating the material to 1000° to 1050°F. with no soak and then furnace cooling, is negligible.

It is often necessary to "stretcher level" when so ordered, particularly on sheets to be used for signs or table tops. This operation consists of gripping the ends of the sheets "viselike" and pulling the sheet just through its yield point. Although such an operation produces an extremely flat sheet, it affects the physical properties to a high degree. For instance, a stretcher-leveled sheet would not be suitable for deep-drawing uses. Such sheets would show Rockwell B hardness values of B40 to B50; 32,000 to 36,000 lb. per sq. in. of yield point; 40,000 to 45,000 lb. per sq. in. of ultimate strength; and 25 to 35% of elongation in 2 in. The percentage of elongation depends on the thickness of the material.

III. Characteristics

The required characteristics of enameling iron are (1) the material must possess the physical and chemical properties and microstructure to meet the requirements; (2) the surface of the sheets must be conducive to good die and enameling performance; (3) the material must be free of nonmetallic impurities that may cause blisters in the pickling or in the enameling operations; (4) it must have good welding properties; (5) it must be free of warpage on requirements where this is an important factor; and (6) the gauge must be uniform.

IV. Effect of Properties and Characteristics on Enameling Shop Performance

In meeting any enameling requirement, the iron must possess the proper physical and chemical properties and microstructure which influence the ultimate performance of the sheets. The properties expected at various stages of production have been outlined and their influence on operations in the consumers' plants will be discussed.

Before the material reaches the enameling shop, it must fabricate properly. To withstand drawing operations successfully, enameling sheets should possess good ductility, be relatively soft, and have a good grain structure. For flatwork and moderate drawing operations where flatness is important, softness and ductility, of course, may be sacrificed to some extent.

Because of its low content of carbon and manganese, enameling iron has an inherently larger grain than other low carbon-rimmed steels; when it is properly processed, it possesses excellent drawing properties. In particularly severe drawing operations, because of the grain size, enameling iron has a tendency when it is drawn to pull coarse (or to "orange peel" as it is sometimes termed) to a greater extent than higher carbon-rimmed steels, for example, sheets used in the hollow-ware or auto-body trade. This factor, however, has proved to be an advantage to the enameler because the open surface favors proper enamel-slip drainage, particularly on large drawn parts. Grain size, within certain limits, may be controlled by the steel supplier, and it is the practice of the supplier in general to strive for a finer grain size on the more severe requirements to avoid breakage caused by coarseness. Figure 4 (*left*) shows the type of grain size favored for normal and moderate drawing requirements. Figure 4 (*right*) shows what is desired in cases of more severe jobs.

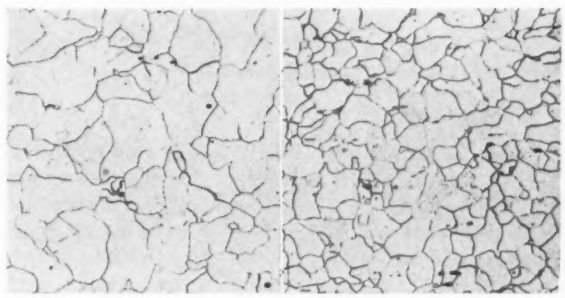

FIG. 4.—(*Left*) Normal and moderate requirements for grain size; (*right*) deep drawing requirements; all 100 ×.

Another important consideration in the fabrication and processing of enameling iron is that of annealing between drawing operations. Although enameling iron is not so susceptible as mild steels to grain growth after straining, it is not entirely free of this condition. For this reason, it is recommended that any annealing between drawing operations be carried out at 1000° to 1200°F. or alternately at not under 1625°F. (sheet temperature). Annealing at 1000° to 1200°F. is sufficient to remove cold-working stresses but it does not affect the grain size. If this temperature range does not condition the ware properly for a subsequent draw, the higher temperature should be employed because this temperature not only removes the stresses but it also produces an equiaxial grain structure. The annealing range of 1200° to 1600°F. is to be avoided because of its effect on the growth of grain size.

Because of the property of age-hardening, it is to the advantage of the manufacturer to process the material as soon as possible after it is received, particularly when it is to be used for the more severe drawing

requirements. Some operations necessitate two or more draws (e.g., some washing-machine tubs). In such procedures, subsequent drawing operations should be carried out immediately. Figure 5 shows the degree of ductility, measured by the percentage of elongation that remains in enameling iron after drawing immediately and after the material has been allowed to age-harden. The data shown in Fig. 5 were obtained by tensile tests, wherein the specimens were pulled in tension after first subjecting them to definite strain.

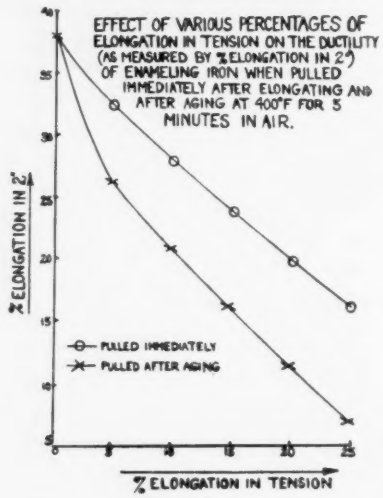
EFFECT OF VARIOUS PERCENTAGES OF ELONGATION IN TENSION ON THE DUCTILITY (AS MEASURED BY % ELONGATION IN 2") OF ENAMELING IRON WHEN PULLED IMMEDIATELY AFTER ELONGATING AND AFTER AGING AT 400°F FOR 5 MINUTES IN AIR.
% ELONGATION IN 2"
PULLED IMMEDIATELY
PULLED AFTER AGING
% ELONGATION IN TENSION

FIG. 5.

The practice is to furnish enameling iron as free as possible from the chemical elements usually associated with iron, such as carbon, manganese, phosphorus, sulfur, and silicon. This is done chiefly to minimize warpage because generally the lower the content of carbon and manganese, when all other variables such as flatness and treatment are the same, the less will be the tendency to warpage during the enameling. As the carbon and manganese increase, the tendency to reboiling is found to decrease.

The surface of enameling sheets is an important characteristic. To insure proper enamel-slip drainage, the sheets should possess appropriate surface roughness. It is possible, however, for surfaces to be too rough, resulting in excessive slip pick up. Surface characteristics also exert an influence on adhesion, but the belief in some quarters that "the rougher the surface, the better the enamel adhesion" is not substantiated by experimental data.

Another important characteristic of enameling iron should be its freedom from nonmetallic impurities which may lead to difficulties in welding, pickling, or enameling. Enameling iron, being highly oxidized, generally contains some small oxide inclusions. These inclusions, which are plastic at hot-rolling temperatures, are elongated in the direction of rolling. If they are numerous or large, they may lead to difficulties in welding, pickling, and enameling. Because the inclusions are nonmetallic in nature, they make the iron difficult to weld and cause difficulty in maintaining an arc if the parts are welded electrically before they are enameled. In the pickling operations, these inclusions may give rise to blisters, which produce blistered enamelware if they are not detected after pickling.

Enameling iron should also possess freedom from warpage, particularly on flatware parts. In addition to its chemical composition, an important requisite of enameling sheets for flat requirements is flatness. A sheet must be flat before it is enameled, if flatness after enameling is to be obtained. Suppliers resort to cold rolling and, in some instances, to stretcher-leveling to control this required flatness. If a flat and ductile sheet is needed, the general practice is to cold roll, which may be followed by a low-temperature annealing to remove the cold-rolling stresses. Where flatness without much ductility is required (for example, sign stock), a customer usually specifies a stretcher-leveled product.

Uniform gauge of sheet is an important characteristic. Gauge variation may be a source of breakage in press-room operations. The requirements may be of such severity that sheets on the light side of the ordered thickness would not meet the job without breakage. Heavier sheets than specified, however, may exceed the die-clearance limitations, causing the metal to shear rather than to draw.

The poor response of enameling iron to box annealing was mentioned and illustrated by grain size in an earlier part of the paper. Enameling iron not only shows a poor response to box annealing but when it is processed in this manner, it generally leads to enameling difficulties. Sheets, furthermore, which receive a box-annealing treatment after normalizing sometimes do not enamel properly.

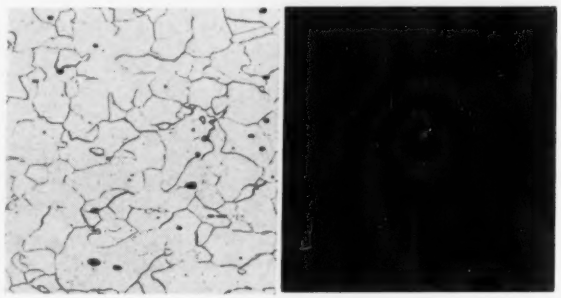

FIG. 6.—(*Left*) Typical normalized, box-annealed enameling iron; (*right*) portion of washing-machine tub with "mirror"-design blisters; 100 ×.

In 1930, Rudyard Porter* encountered this enameling difficulty in low carbon-rimmed steel supplied to the hollow-ware trade. An extensive investigation at the time led to the same condition taking place in enameling iron. From the results, it was concluded that, to enamel satisfactorily, material that is box-annealed only following hot or cold reduction should be annealed at temperatures not exceeding 1250°F. Annealing after normalizing and cold rolling, furthermore, should be carried out as low as 1000° to 1100°F. At higher temperatures, the material showed enamel defects, generally copperheads or blisters.

* Then with the American Sheet & Tin Plate Co. (later with the Carnegie-Illinois Steel Corp.).

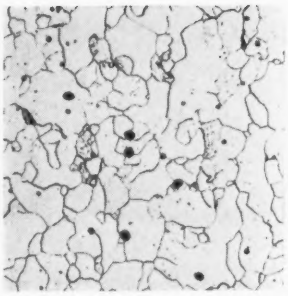

FIG. 7.—Microsection of defective material; no abnormal condition.

FIG. 8.—Material heated at 1580° to 1600°F. for 1 to $1^1/_2$ minutes; *left* (100 ×), *right* (1000 ×).

A brief résumé of Porter's findings may be of interest. Figure 6 (*left*) shows the microstructure of a typical normalized, box-annealed enameling iron. From all appearances, this material would be expected to enamel satisfactorily, but defects became evident as shown by Fig. 6 (*right*), which is a portion of a formed washing-machine tub containing "mirror"-design blisters. This defect is also termed "curtains" by some enamelers. A microsection taken from the defective material, Fig. 7, revealed no abnormal condition.

Experimentation with the unenameled material, however, revealed some interesting facts. Different experiments to approach what actually happened during the enameling operation showed that heating the material at 1580° to 1600°F. (ground-coat enameling temperatures) for 1 to $1^1/_2$ minutes gave a microscopic condition shown in Fig. 8. The dark areas (at 100 and 1000 ×) were found to be rich in carbon and consisted principally of pearlite. These patches or areas, for want of more suitable terminology, were called "rosettes." It was found furthermore that prolonged heating for three or four minutes (time for firing ground coats) caused these carbides to go into solution. When ground coats, however, were applied to material susceptible to this condition, the oxides in the enamel frit at high temperatures combined with some of the available carbon to form carbon monoxide and carbon dioxide which, as a gas, permeated the viscous enamel frit. This resulted in the defects of the nature illustrated.

V. Summary

The various items discussed may be summarized as follows: (1) Enameling iron is a commercially pure iron. (2) Particular attention must be given in the hot rolling of this product because of its "red-short" range. (3) As a "hot-strip" product, enameling iron is not particularly ductile and does not possess a good grain structure. (4) As a "cold-reduced only" product, enameling iron loses practically all semblance of ductility and grain size. (5) As a "cold-reduced, normalized, pickled, cold-rolled" product, enameling iron shows good drawing and enameling properties. (6) Enameling iron shows a poor response to box annealing after cold or hot reduction; if annealing temperatures exceed 1250°F. (approximately), "rosettes" usually result which cause enameling defects; annealing followed by cold reduction, normalizing, pickling, and cold-roll treatment must be done at temperatures low enough to avoid "rosettes." (7) Enameling iron, like mild steels, will harden with age. (8) Enameling iron must be ductile enough to meet the customers' fabricating requirements. (9) Enameling iron must be of uniform gauge, flat (where flatness is important), and it must be free of excessive warpage. (10) The surface of the sheets should be of proper roughness to facilitate proper enamel-slip drainage and not impair the drawing quality. (11) Enameling iron should be free of nonmetallic inclusions which may have a harmful influence on the drawing, welding, pickling, or enameling properties.

Acknowledgment

The writers acknowledge the assistance of the Gary Sheet Mill personnel in the preparation of this paper and wish to express their appreciation to those who read and contributed suggestions to this work.

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PARTICLE-SIZE DISTRIBUTION OF INGREDIENTS VERSUS BODY PROPERTIES*

By J. H. Koenig

Abstract

Bodies of the same formula were prepared with the grain-size distribution of certain materials introduced as the variable. The properties tested include workability and castability, flexural strength, elasticity, thermal expansion, and thermal endurance.

I. Effect of Flint Particle Size on Properties of Flint-Clay Mixtures

The effect of the particle size of flint on the properties of flint-clay mixtures was determined for (1) a coarse-ground flint (140-mesh), (2) a regular potter's flint, and (3) a very fine-ground flint (99.5% through 325-mesh). The particle-size distributions are given in Fig. 1. The Andreasen pipette method[1] was used to measure the grain-size of the materials.

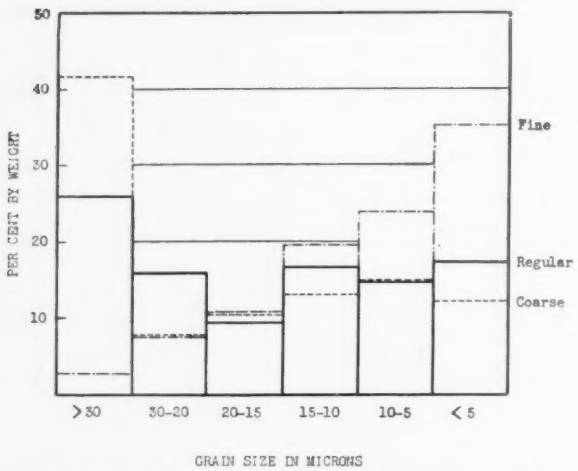

Fig. 1.—Particle-size distribution of the flint tested.

The finely ground flint had a considerable number of particles less than 1 micron in size (about 6%), whereas the regular and coarse flints showed only traces of this size.

An English and an American ball clay were then blended with each of these flints. The data for the 50% English clay-flint mixtures are shown in Fig. 2; Fig. 3 gives data for the 50% American clay-flint mixtures.

A noticeable increase occurred in water of plasticity with decreasing particle size, but no effect of the particle size of flint on the dry strength was evidenced. For the same flint grain size, the English ball clay gave higher strength, although when it was completely deflocculated this clay was coarser grained than the domestic clay. There appeared to be a slight increase in drying shrinkage with decrease in flint size, and this effect was more pronounced in the American clay.

The degree of flint subdivision was reflected to a greater extent in the fired properties, that is, the finer the size of flint, the higher the degree of vitrification. The firing shrinkage increased with a decrease in flint particle size and at a considerably greater rate in the English ball-clay mixtures. The amount of absorption fell off and the strength increased in both cases with decreasing flint particle size.

The microstructure of the American ball clay-flint mixtures fired to cone 12^5 are shown in Fig. 4. The variations in flint particle size correspond with the size found in the microstructure of these bodies.

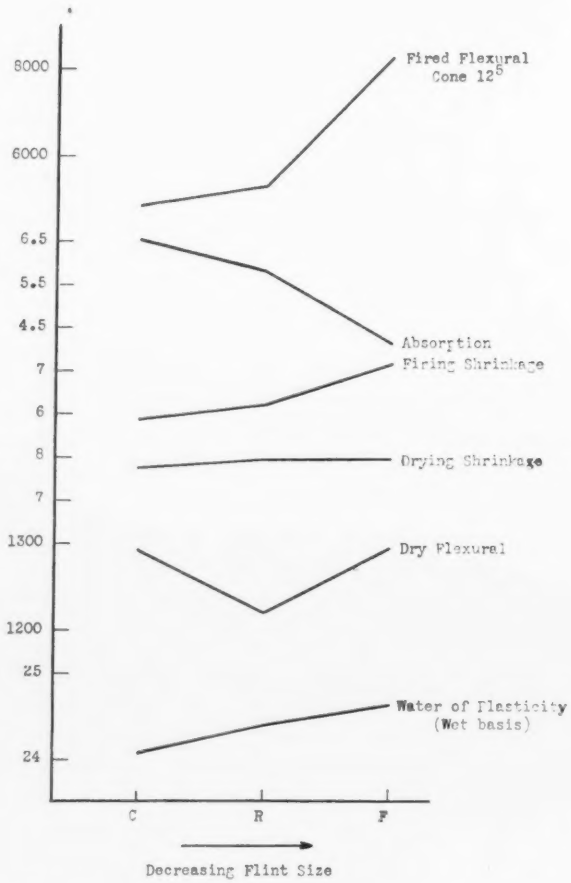

Fig. 2.—Properties versus flint particle size in English ball clay-flint mixtures; *C*, coarse flint; *R*, regular potter's flint; *F*, fine flint (325-mesh).

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 9, 1940 (Materials and Equipment and White Wares Divisions). Received July 1, 1940.

[1] G. A. Loomis, "Grain Size of Whiteware Clays as Determined by the Andreasen Pipette," *Jour. Amer. Ceram. Soc.*, **21** [11] 393–99 (1938).

II. Effect of Flint Particle Size on Properties of a Vitreous China Body

Three bodies of the same formula (cone 12 vitreous china body) were prepared using (1) regular potter's flint, (2) one-half regular flint and one-half fine 325-mesh flint, and (3) all 325-mesh flint. The data for these bodies are presented in Fig. 5. The jiggerman found no marked difference in their workability.

The microstructure of the body containing regular potter's flint is shown on Fig. 6 (*A*); Fig. 6 (*B*) shows the same body composition except for the replacement of the regular flint by the fine 325-mesh flint.

Figure 7 gives the thermal-expansion characteristics of these bodies and shows that as the particle size of flint is reduced, the thermal expansion of the body increases. The smaller the size of quartz, the steeper also is the expansion curve.

The question naturally arises why the body expansion is not lowered by greater quartz solution when a finer-grained size of quartz is incorporated in the body. Harkort[2] suggested that coarse quartz cannot fully exert its contraction and expansion on the clay or the decomposition products of the clay surrounding it. The more finely the quartz is divided and the more densely the clay is incorporated with it, the more the quartz will exert these properties.

In work at the National Bureau of Standards,[3] it was observed that bodies containing coarse-grained quartz can be completely dispersed and surrounded by the other ingredients, principally clay. The quartz particles, on cooling, may shrink away from the surrounding mass of the body, leaving a space in which these particles are free to expand and contract to a limited amount and therefore having only a limited influence on the over-all expansion. The total differential contraction in the fine-grained bodies is not sufficient for the quartz to free itself, and the quartz therefore can exert a relatively greater influence on the bulk expansion.

There was a slight improvement in thermal endurance as the flint size was reduced. Thermal-shock tests were conducted on bisque-ware specimens that were left in an oven for 2 hr. at 200°C. before testing. The test consisted of pouring 50 cc. of water at 25°C. into the center of the dish through a hole provided in the top of the oven and observing the number of such cycles to produce failure.

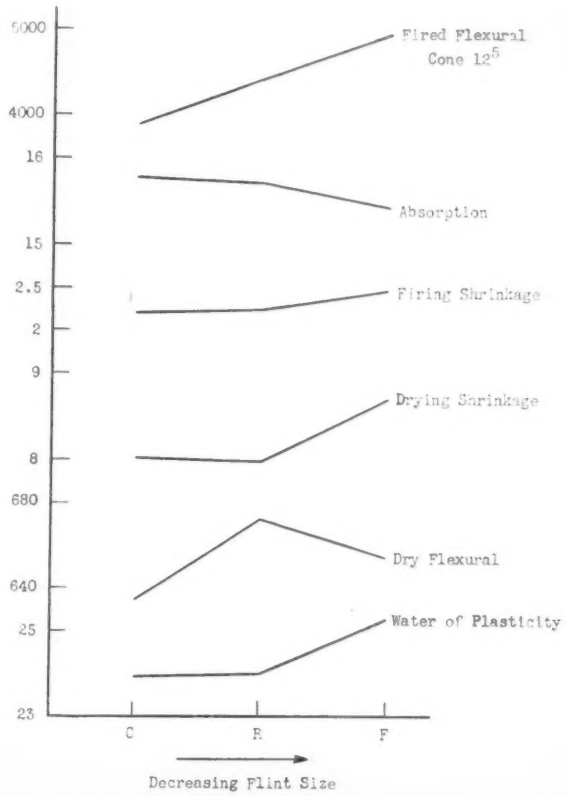

FIG. 3.—Properties versus flint particle size in American ball clay-flint mixtures.

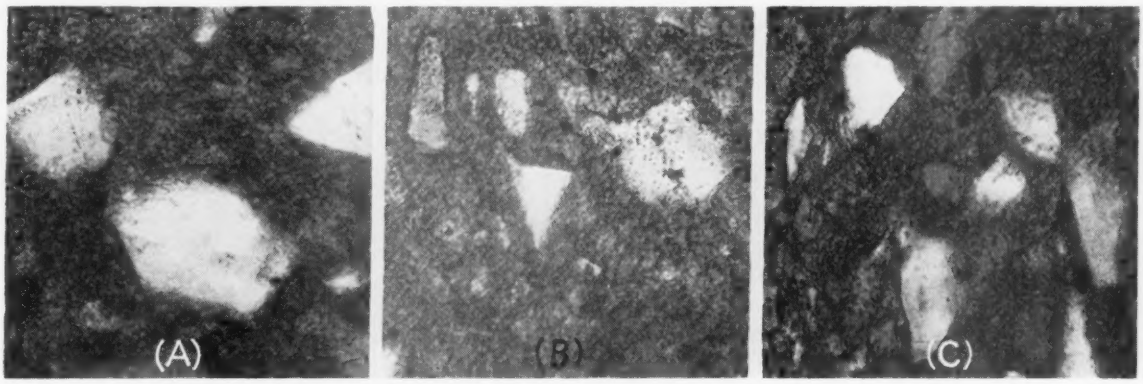

FIG. 4.—Microstructure of ball clay-flint mixtures fired to cone 12[5], 475 ×; (*A*) coarse flint; (*B*) regular potter's flint; (*C*) fine flint (325-mesh).

[2] H. Harkort, "Effect of Particle Size of Quartz on Properties of Whiteware Bodies," *Ber. deut. keram. Ges.*, **9** [8] 476–89 (1928); *Ceram. Abs.*, **7** [12] 844 (1928).

[3] R. F. Geller, D. N. Evans, and A. S. Creamer, "Effects of Particle Size of a Potter's 'Flint' and a Feldspar in Whiteware," *Bur. Stand. Jour. Research*, **11** [3] 327–40 (1933); R.P. 594; *Ceram. Abs.*, **12** [12] 427 (1933).

III. Variation of Particle-Size Distribution in Commercial Potter's Flint

Samples from 25 carloads of flint were measured (for data see Fig. 8). The solid line is the average for all tests; the dotted lines represent the maxima and minima for distribution intervals for all of the samples tested. The agreement of the data from sample to sample in a number of cases was quite good, but sufficient variation existed to warrant question as to whether more uniformity should not be sought.

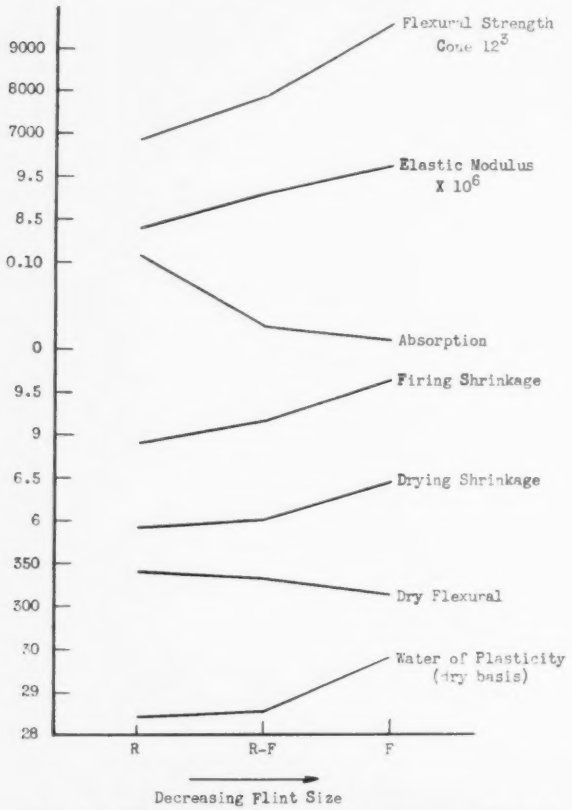

FIG. 5.—Effect of flint particle size on properties of a vitreous china body; *R*, regular potter's flint; *F*, fine flint (325-mesh); *R–F*, one-half of each introduced as flint content.

IV. Effect of Feldspar Particle Size on Properties of a Vitreous China Body

Another test was made to show the effect of the grain size of feldspar in the same vitreous china body. Two feldspars were used in this body. The variation in the grain-size distribution of these feldspars is shown in Fig. 9. The solid lines represent the distributions of the samples as received for use, and the dotted lines are samples of the same feldspars which received additional grinding in the laboratory (72 hr. of dry grinding in a small 1-gallon ball mill).

The properties of these bodies incorporating the feldspars (commercially ground and the more finely ground) are given in Fig. 10. There was a slight increase in water requirement, dry shrinkage, and dry flexural strength. The body containing the finer-ground feld-

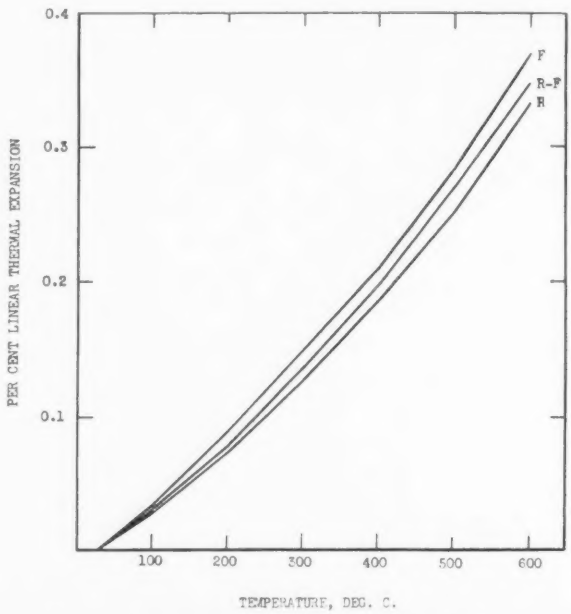

FIG. 7.—Thermal-expansion characteristics of a vitreous china body using flint of various grain sizes; *R*, regular potter's flint; *F*, fine flint (325-mesh); *R–F*, one-half of each.

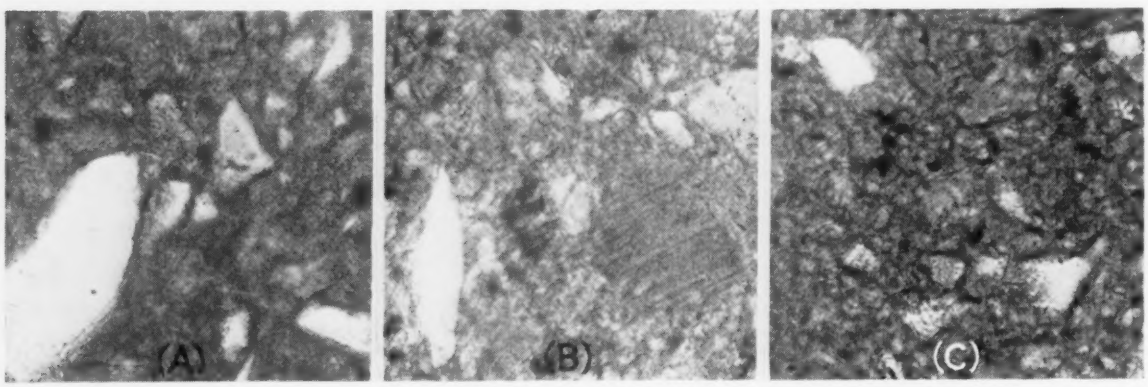

FIG. 6.—Microstructure of a vitreous china body fired to cone 12^3, 475 ×; (*A*) regular potter's flint; (*B*) fine flint (325-mesh); (*C*) fine flint (325-mesh) and fine-ground feldspar.

spars evidenced greater vitrification when it was fired at cones 11[1] and 13[2]. The firing shrinkage and strength were greater for the finer-ground feldspar body and there was less absorption. The relative increase in strength was greater at the lower temperature, which may be significant, i.e., an extension of the firing range.

Other bodies were prepared containing finely ground flint as well as feldspar. These bodies had considerably greater strength and rigidity and higher thermal expansion than the regular body, and they also showed greater strength than the bodies in which fine flint and regular feldspar or regular flint and fine feldspar were used. Figure 6 (*C*) shows the microstructure of the fine (325-mesh) flint fine-feldspar body.

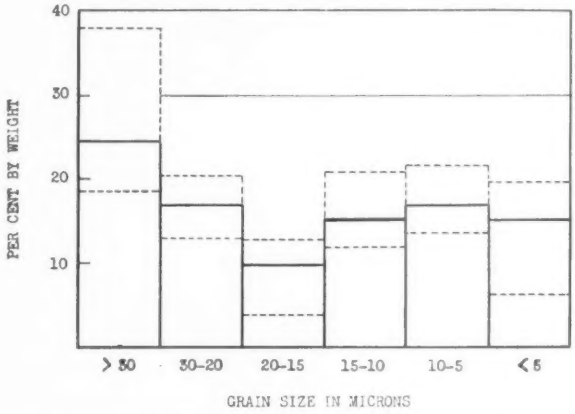

FIG. 8.—Variation in particle-size distribution of a commercial potter's flint; *solid lines*, average of 25 tests on car samples; *dotted lines*, maxima and minima variations in the distribution interval for all samples tested.

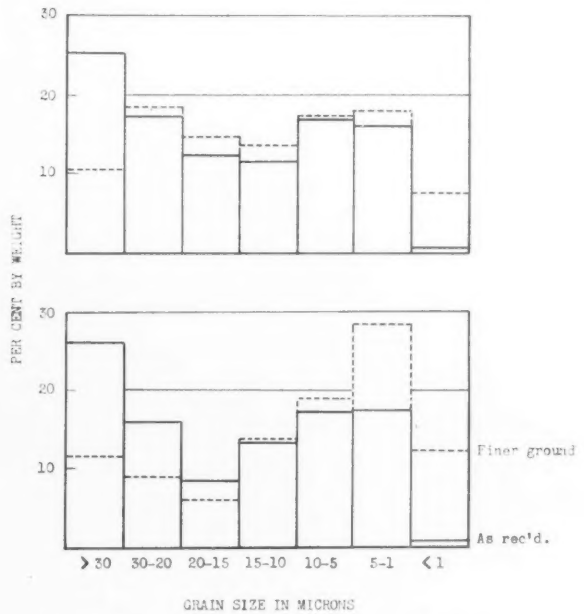

FIG. 9.—Particle-size distribution of feldspars; *solid lines*, distribution of samples commercially ground; *dotted lines*, the more finely ground feldspars.

V. Variation in Particle-Size Distribution of Two Commercial Feldspars

Sixteen car samples of two feldspars received during the past year were tested for grain-size distribution. These data are given in Fig. 11, in which the solid line is the average of all tests, whereas the dotted lines represent the maxima and minima for distribution intervals for all of the samples. Considerable variation is shown in these tests.

VI. Variation of Particle Size of Kaolin in a Vitreous China Body

Only the grain size of a kaolin was varied in this test. The particle-size distribution of the N. C. kaolin is shown in Fig. 12 as well as the finer fractions of the same kaolin obtained by a different refinement carried out to eliminate the coarser grain.

The body with the fine-grained kaolin had a slightly greater water requirement, higher dry strength, and higher drying shrinkage; when it was fired it had greater shrinkage and strength and a lower absorption than the same body containing the coarse-grained kaolin. A slight preference was given by the jiggerman to the body in which the fine-grained kaolin was used.

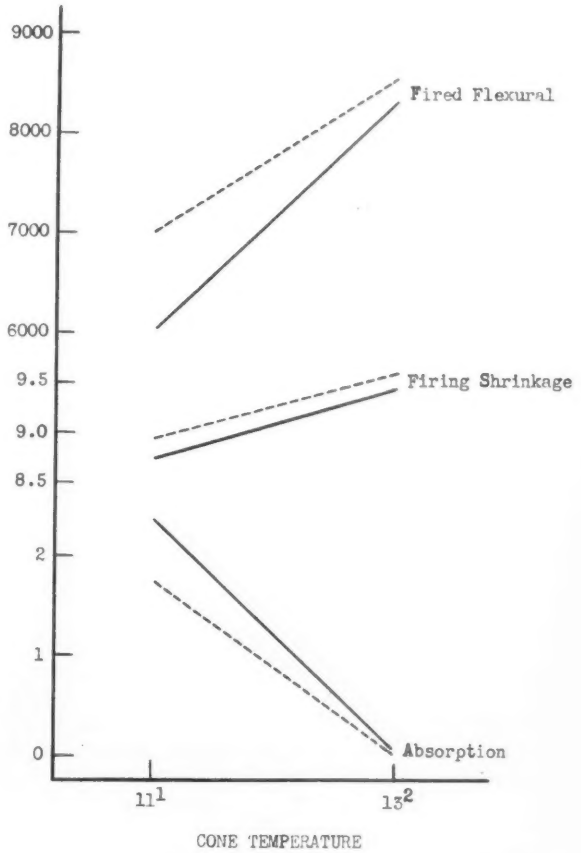

FIG. 10.—Effect of fineness of feldspar content on properties of a vitreous china body; *solid lines*, data on body with commercially ground feldspars; *dotted lines*, body with more finely ground feldspars.

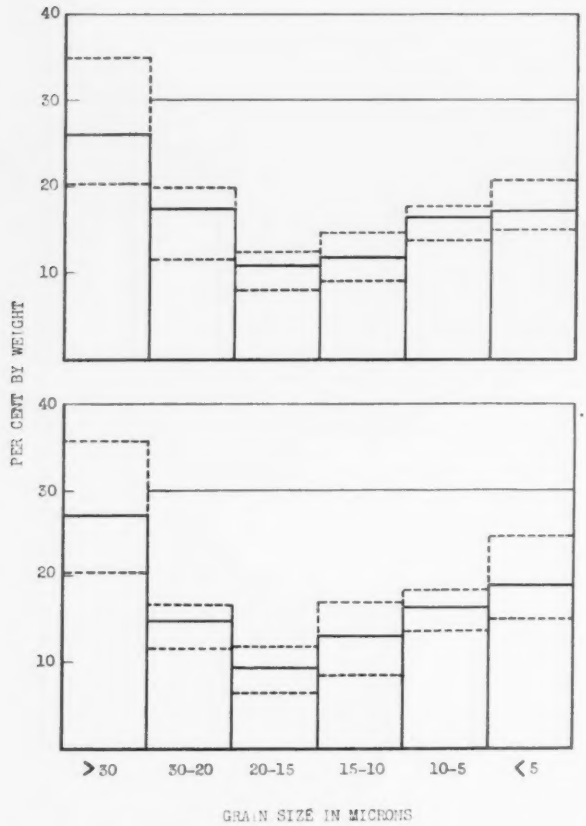

FIG. 11.—Variation in particle-size distribution of two commercial feldspars from car-sample tests; *solid lines*, average of all tests; *dotted lines*, maxima and minima for distribution intervals.

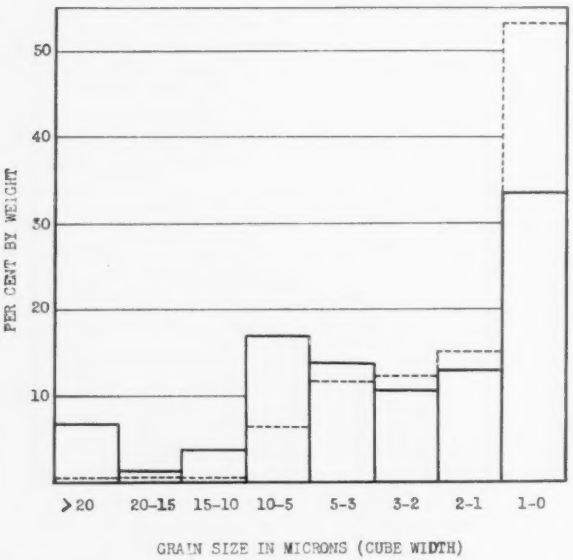

FIG. 12.—Particle-size distribution of kaolins in a vitreous china body; grain size in this case only is expressed as cube width; *solid lines*, kaolin as supplied; *dotted lines*, finer fractionation of same kaolin as used in same body.

VII. Effect of Ball Milling Body Slip

Specimens were cast from slip ground in a ball mill for 24 and 72 hr., respectively. The particle-size distribution of solids in the original slip and in the slip after 72 hr. of ball milling is shown in Fig. 13.

The slips were adjusted to similar consistency by the use of electrolyte additions. With the additional amount of finer grains, or greater surface, the electrolyte sorption and requirement naturally become greater. Progressive electrolyte additions were made to the 24- and 72-hr. ball-milled slips, and a continuous increase in fluidity and pH followed; the liquefaction was carried to similar fluidity. The properties of the specimens cast from these slips are plotted on Fig. 14.

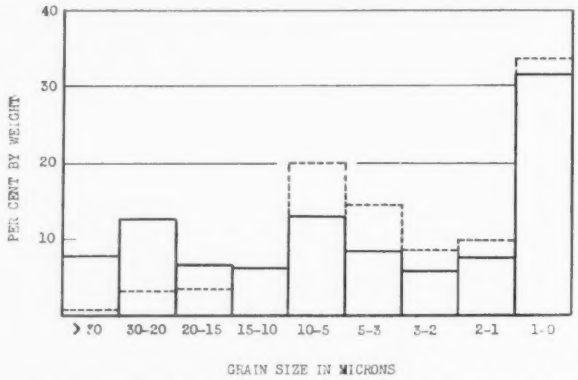

FIG. 13.—Particle-size distribution of a vitreous china body and of the same body ground for 72 hours; *solid lines*, original slip; *dotted lines*, ball-milled slips.

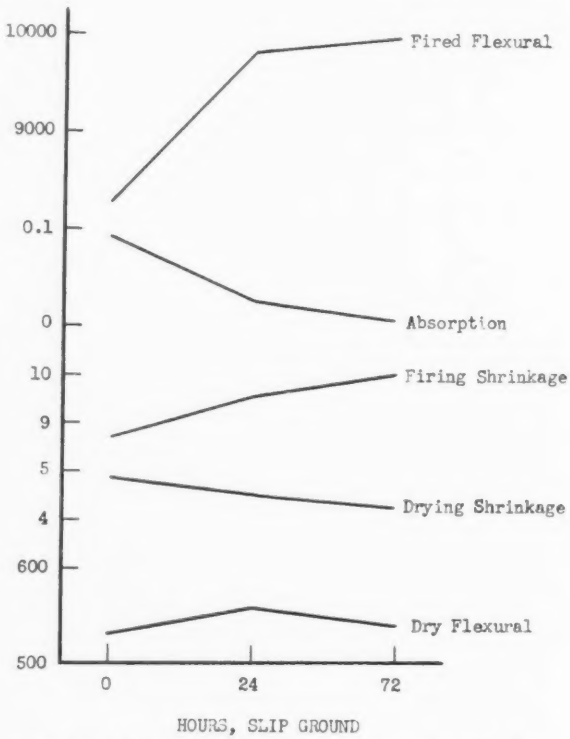

FIG. 14.—Effect of ball milling on properties of a slip.

Figure 15 (*A*) shows the microstructure of a thin section of a specimen cast from the original slip; Fig. 15 (*B*) shows a specimen cast from the slip which was ball milled for 72 hr. The relative quartz size and greater homogeneity of structure are apparent. The fracture of the 72-hr. milled specimens was much more glassy and homogeneous than the nonmilled slip specimens, and the specimens milled for 24 hr. were intermediate in degree of smoothness and nature of fracture. This difference in fracture was decidedly marked.

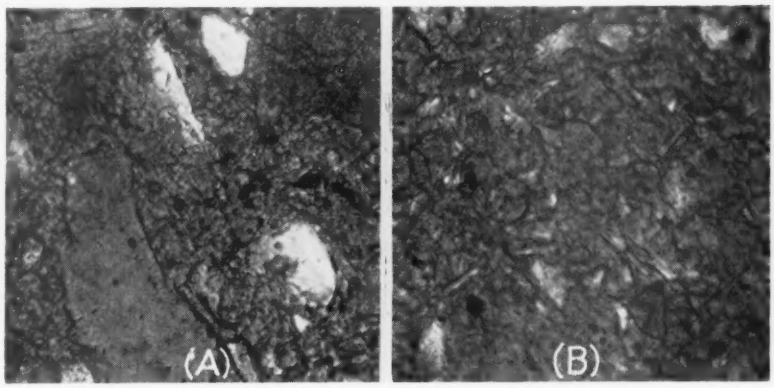

FIG. 15.—Microstructure of specimens showing effect of ball milling of slip, 475 ×; (*A*) specimens cast from blunged slip; (*B*) same slip ball milled for 72 hours and fired to cone 12 [2].

These same results may be achieved, in part, by using more finely ground nonplastics directly in the blunged slip.

VIII. Summary

(1) In equal part clay-flint mixtures, the effect of flint subdivision appears to be greater in the fired than in the dry properties. The fineness of the flint exerts a strong effect on vitrification.

(2) Varying the particle size of the flint incorporated in a vitreous china body gives similar results. There is no marked difference in workability, and vitrification is accelerated by decreasing the flint size. As the flint is reduced in size the thermal expansion of the body is increased and there is a slight improvement in thermal endurance. Although increasing flexural strength may augment the endurance, the increase of thermal expansion and of body rigidity simultaneously do not enhance this property.

(3) Increased vitrification may be secured by using more finely ground feldspar, but the changes in the degree of vitrification by varying the size of the feldspar appear to be relatively less important than those effected by varying the flint particle size, especially at the normal firing temperature of the body tested. The use of finely ground flint and feldspar gives greater strength, rigidity, and higher thermal expansion. When these finely ground materials are used, the flux content may be reduced appreciably and the same degree of vitrification may be obtained as that of the regular body or the body with normal flux content may be matured at lower temperature.

(4) Particle-size measurements on commercial flint and on feldspar indicate a considerable variation in grain-size distribution from shipment to shipment.

(5) The substitution of more of the finer fractions of the same kaolin in a vitreous china body gives higher dry strength and drying shrinkage and, on firing, greater vitrification than the same body containing the coarser-grained kaolin; workability is improved.

(6) Ball milling the slip provides a reduction chiefly in particle size of nonplastics, and ware cast from such slip is more vitreous and possesses decidedly a more glassy and homogeneous fracture. The same results may be achieved in part by using finer-ground nonplastics directly in the blunged slip.

(1940)

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EFFECT OF WATER CONTENT AND MIXING TIME ON PROPERTIES OF AIR-SETTING REFRACTORY MORTARS CONTAINING SODIUM SILICATE *

BY R. A. HEINDL AND W. L. PENDERGAST

ABSTRACT

The relation was determined between the strength after drying and the water content of a fire clay from Ohio, a mix of the fire clay and grog, and this mix containing 25% of a solution of sodium silicate. The change in consistency of the latter mix with time of mixing was determined by the use of the flow table. The strengths after drying and the pyrometric cone equivalents of a Pennsylvania fire clay, to which different percentages of two powdered sodium silicates of different soda-silica ratios and water had been added, were also determined. Four commercial air-setting mortars and the Ohio clay were tested for strength after mixing for $^1/_2$ to 20 hours and drying. After each 5 hours of mixing, the mortars were soaked for 19 hours. Some data were obtained on carbonates in mortars stored in steel drums and those stored in burlap sacks and on the effect of such carbonates on the strength of the mortars.

I. Introduction

Air-setting refractory mortars containing sodium silicate are marketed both in the wet and in the dry condition. A variable amount of mixing is necessary to remix mortars marketed wet,[1] depending on the degree to which the solids have remained in suspension during storage. In the case of mortars marketed dry, however, it is necessary to mix them thoroughly with water not only to obtain a uniform consistency but also to dissolve the sodium silicate. To further this solution, some manufacturers recommend a soaking period of from 12 to 36 hours before the mortar is used. In addition to the extent of the soaking period, the quantity of water necessary to bring the mortar to the desired working consistency and the length of time of mixing are variables which therefore could have a considerable effect on the working properties as well as on the strength of the mortar. To determine the effect of these variables, tests were made of the strength of several mortars after air setting. The results obtained are given in this report as well as some data on the change in consistency of the mortars when the time of mixing was increased and on the effect on the refractoriness and strength of changing the content of sodium silicate.

II. Materials and Tests

The materials used in the tests were a fire clay from Ohio and one from Pennsylvania; a ball clay-kaolin grog of approximately 20% porosity; sodium silicate in solution of a soda-silica ratio 1:3.86 (6.4% of Na_2O and 24.7% of SiO_2); two sodium silicates in powder form, which had soda-silica ratios of 1:3.2 and 1:2, respectively; and six proprietary brands of air-setting mortars marketed in the dry condition. The 1:3.2 dry sodium silicate is generally used by manufacturers in preparing air-setting mortars even though it is much less water-soluble than the 1:2 sodium silicate.

The grog was composed of (*a*) $16^2/_3$% of material which passed a No. 20 United States standard sieve and was retained on a No. 40, (*b*) $66^2/_3$% which passed a No. 40 and was retained on a No. 100 sieve, and (*c*) $16^2/_3$% which passed a No. 100 sieve.

The strength after drying was determined for (1) the Ohio clay and water; (2) the $66^2/_3$% Ohio clay, $33^1/_3$% grog, and water; (3) the $66^2/_3$% Ohio clay and $33^1/_3$% grog mix with 25% by weight of sodium silicate in solution; (4) the Pennsylvania clay and water; (5) the Pennsylvania clay to which was added water and from 5 to

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 9, 1940 (Refractories Division). Received June 13, 1940.

[1] R. A. Heindl and W. L. Pendergast, "Properties of Air-Setting Refractory-Bonding Mortars of the Wet Type," *Jour. Research Nat. Bur. Stand.*, **23** [1] 7–38 (1939); R.P. 1219; *Ceram. Abs.*, **18** [11] 301 (1939).

12.5% of one of the silicates in powder form; (6) and four brands of air-setting mortars and water.

The flow-table test is described in the Federal Specification SS-C-158[2] and also in the A.S.T.M. Tentative Standard for Masonry Cement, serial designation C91-38T.[3]

The pyrometric cone equivalent was determined according to the A.S.T.M. standard method C24-35.[4]

The carbon dioxide content of the proprietary mortars was determined by the method of Hillebrand.[5]

All of the mortars were mixed in a 2-blade kneading machine. Separate portions of two of the mortars were also mixed in a small mortar box with a hoe to simulate conditions used by furnace builders. The consistency for troweling was judged by "feel."

The strength determinations were made on bars, 6 by 1 by 1/4 in., which were cured for 48 hr. in a humidity of approximately 60% and at 20° to 22°C., then for 18 hr. at ordinary temperature and humidity, followed by 27 hr. in a drying oven at 105° to 110°C. The specimens were broken with center loading, and the span was usually 5 in.

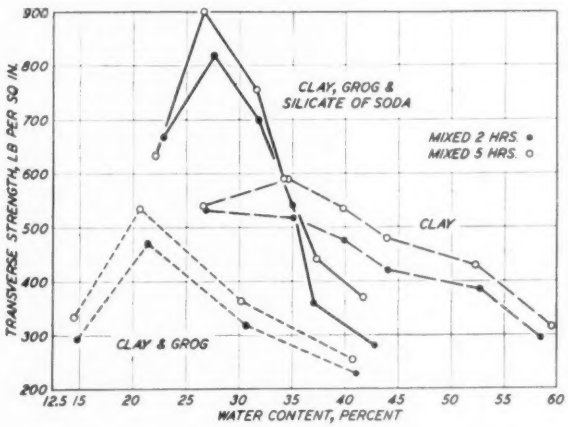

FIG. 1.—The effect of change in percentage of mixing water on the strength after drying of three refractory mixes made with an Ohio fire clay. For troweling purposes, the mixes of the clay containing 35% and less of water, those of clay and grog containing 21% and less, and those of the clay, grog, and sodium silicate containing 26% and less were too dry. All other mixes were satisfactory for troweling except those of the clay containing about 59% of water.

In preparing the batches for the study of the effect of mixing time, the procedure was to start with as large a batch as could be conveniently mixed in the machine (20 to 25 lb.). Portions of the batches were taken after increasing intervals of time, and test specimens of each were prepared. In the study of the effect of different percentages of water on the strength of the materials, individual batches were prepared for each test.

To minimize moisture loss and to maintain a water content approximately constant, the machine was kept covered during mixing.

The strengths given, with few exceptions, represent the average of not fewer than ten specimens. Five of these specimens were broken with that surface in compression which was uppermost when the specimens were molded and the other five were broken with that surface in tension. This method was used because, as pointed out by Heindl and Pendergast,[1] the strength depends to some extent on which of the two surfaces is in compression.

The loss in weight of the mortars dried at approximately 110°C. was considered to be the water content and is reported in percentage of the dry weight.

III. Results and Discussion

(1) Effect of Water Content on Strength of Specimens

Figure 1 shows the relation between the water content and the strength of the laboratory-prepared specimens (mixed for 2 and 5 hr., respectively, and dried), made of Ohio fire clay with water; of this clay and grog with water; and also of this clay, grog, and a solution of sodium silicate with water.

In five of the six cases, the strength of the mixes reached a maximum with a certain water content.[6] The increase to maximum strength with subsequent decrease was the most pronounced in the mortar containing the sodium silicate and least in the clay. Each mix, however, was far too stiff for satisfactory troweling at the consistency at which maximum strength was obtained. The water content had to be increased by several percent to obtain what was considered to be a satisfactory troweling consistency. Although insufficient data were obtained to reach definite conclusions, the results indicate that the working range for good troweling was greatest with the clay alone.

The results show that 5 hr. of continuous mixing of the mortar caused some increase in the strength above that obtained with 2 hr. of mixing. The average deviation of the strengths from the mean, computed for the values shown in Fig. 1, ranged from 2 to 17%.

(2) Relation of Flow (Workability), Strength, and Time of Mixing of Laboratory-Prepared Mortars

Figure 2 shows the relation between mixing time and flow-table readings of laboratory-prepared mortars Nos. 1 and 2. These mortars, made with Ohio fire clay, grog, sodium silicate in solution, and water, differed only in the water content, which was 33 and 37%, respectively, and although they were not prepared at the same time as the clay-grog-sodium silicate mortar referred to in Fig. 1, they are alike in composition.

The graph shows that the strength of mortar No. 1 was increased from 310 to 800 lb. per sq. in. simply by

[2] Cements, hydraulic; General Specification.

[3] *Proc. A.S.T.M.*, **38** [Part I], 731–37 (1938).

[4] Manual of A.S.T.M. Standards on Refractory Materials, pp. 53–57 (1937).

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[6] Similar results have been reported in a study of a clay and of a clay and grog mixture (see R. J. Montgomery and C. E. Fulton, "Influence of Varying Water Content in a Fire-Clay Mixture," *Trans. Amer. Ceram. Soc.*, **17**, 436–49 (1915)).

increasing the time of mixing from $^1/_2$ to 7 hr. Although the mortar increased in strength and the water content remained very nearly constant, the fluidity of the mortar decreased with time of mixing until it had no flow at the end of 7 hr. The consistency of the mortar was too stiff to permit satisfactory troweling when the flow-table reading was below 30.

The trend in properties for mortar No. 2 was similar.

For the strength values given in Fig. 2, the average variation from the mean ranged from 4 to 24%. The highest variations were found with the low strength values as was expected.

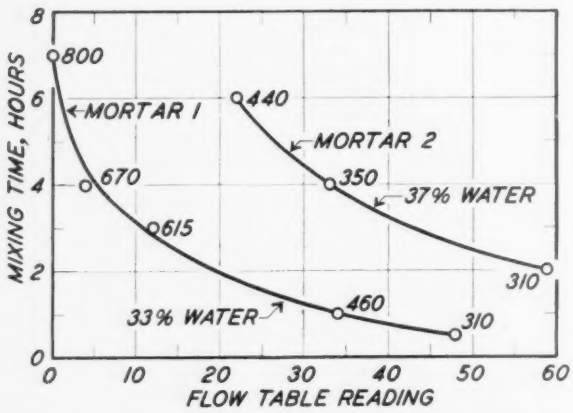

FIG. 2.—The relation of mixing time and flow-table readings (workability) of mortars Nos. 1 and 2. The values opposite each plotted point represent transverse strength in pounds per square inch. The mortars, which differ only in water content, were made with Ohio clay, grog, and silicate of soda.

(3) Effect of Two Sodium Silicates, Added in Powder Form, on Air-Setting Strength of Mortars

Figure 3 shows the strength of mortars Nos. 3 and 4 with varying percentages of sodium silicate after mixing periods of 15 minutes and 1 hr. The figures show that for either mortar, 5% of sodium silicate was insufficient to produce pronounced improvements in strength. Mortar No. 3, however, which contained the Pennsylvania clay and the more alkaline sodium silicate (1:2 soda-silica ratio), showed an increase in strength from less than 100 lb. per sq. in. for the clay without any sodium silicate to about 1200 lb. per sq. in. when 7.5% had been added. Mortar No. 4, which contained the Pennsylvania clay and the less alkaline silicate (1:3.2 soda-silica ratio), under the same conditions showed an increase to less than 600 lb. per sq. in. The strengths of the two mortars were not greatly different, however, when 10% or more of either of the silicates was used.

Mixing for 1 hr. instead of for 15 minutes did not give appreciably higher strength, except for that mix of mortar No. 4 which contained 10% of sodium silicate.

For the strength values given in Fig. 3, the average variation from the mean ranged from 4 to 15%.

(4) Effect of Mixing and Soaking Time on Strength

(*A*) *Ohio Fire Clay:* Figure 4 shows the effect of the length of time of mixing and of soaking on the strength after drying a mix of the clay and water. Specimens were made after $^1/_4$, 1, 3, 5, 10, 15, and 20 hr. of mixing with an intervening soaking period of 19 hr. after each 5 hr. of mixing. After 15 minutes of mixing, the clay had a strength of 430 lb. per sq. in.; after 5 hr., it had increased to 520 lb. per sq. in.; and after 20 hr. with soaking periods of 19 hr. after each 5 hr. of mixing, the strength of the clay was 690 lb. per sq. in.

If the specimens were broken with that surface in compression which was uppermost when the specimens were made, the modulus of rupture was then at least 10% greater than if that surface was in tension. The reverse was noted by Heindl and Pendergast[1] in their study of air-setting refractory mortars.

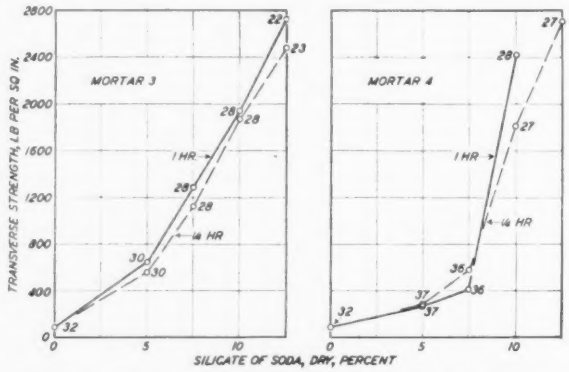

FIG. 3.—Comparative strengths of two laboratory-prepared mortars consisting of fire clay and varying percentages of sodium silicate in powdered form and water after $^1/_4$ hr. and 1 hr. of mixing, and then drying. Mortar No. 3 contained a sodium silicate of 1:2 soda-silica ratio, and mortar No. 4 contained a ratio of 1:3.2. The percentages of water are adjacent to the plotted strength values.

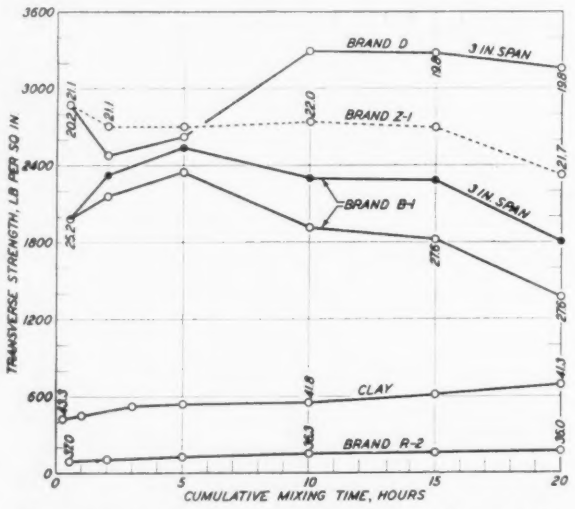

FIG. 4.—The effect of mixing time and of intermittent mixing and soaking on the air-set strength of an Ohio fire clay and 4 brands of air-setting mortars of the dry type. After each 5 hr. of mixing, the mortars were soaked 19 hr. (overnight). Specimens were broken over a 5-in. span except as noted. The percentages of water are adjacent to the plotted strength values.

For the values given for this clay in Fig. 4, the average variation from the mean ranged between 6 and 8%.

(*B*) *Commercial Air-Setting Refractory Mortars:* Figure 4 also shows the effect of mixing and of soaking time on the strength, after drying, of four proprietary mortars when the mixing water remained approximately constant. Specimens were made after 1/2, 2, 5, 10, 15, and 20 hr. of mixing. There was, however, an intervening soaking period of 19 hr. after each 5 hr. of mixing. The specimens in each case were made from the same batch which, after the first 1/2 hr. of mixing, was of a troweling consistency. As the length of the mixing time was increased more than 2 hr., the mortars stiffened gradually, and after 20 hr. of mixing, brand R was entirely unsatisfactory for troweling. Many of the test specimens, made from mortars B and D, after 20 hr. of mixing and 57 hr. of soaking, were discarded because they had cracked badly during drying.

The trends of the strengths of the mortars with length of time of treatment are different. Mortar B developed its greatest strength with 5 hr. of mixing; mortar Z was strongest when mixed 1/2 hr.; mortar D, which was weaker after mixing for 2 or 5 hr. than it was after 1/2 hr., developed its greatest strength with 19 hr. of soaking and 10 hr. of mixing.

The strength of mortar R was very low after 1/2 hr. of mixing and changed little with soaking and longer mixing (see Fig. 4). The specimens in this case were made about 8 months after the mortar had been stored in the laboratory in its original container, a burlap or jute sack with a "moistureproof" lining.

For the strength values in Fig. 4, the average deviation from the mean ranged from 3 to 15%.

Mortar D developed a strength of 2400 lb. per sq. in. and mortar B, 1000 lb. per sq. in. after 15 minutes of mixing with a hoe in a mortar box. An additional overnight soaking and mixing for 1/2 hr. with the hoe did not change these strengths materially. This is in contrast to strengths of 2900 and 2000 lb. per sq. in., respectively, which developed after 1/2 hr. of machine mixing.

The average strength of the mortars was greater when broken with that surface in tension which was uppermost when the specimens were made than when that surface was in compression. The differences in strength were 28, 49, 27, and 15%, respectively, for mortars B, D, R, and Z.

This study indicates that it is unnecessary to subject air-setting mortars to long soaking periods and that long mixing periods may be undesirable. As the properties of such mortars apparently vary with mixing and soaking time, a definite requirement for such treatment should be stipulated in specification requirements for the air-setting strength of mortars marketed dry.

(5) Effect of Storage

The information given in Table I shows that mortars stored in iron drums have a comparatively high strength, whereas those stored in "moistureproof" sacks have a comparatively low strength. The results of the strength tests given in Table I show that, of the mortars received in sacks, Z-1, when tested within a week of its receipt, was the only one which had a high air-setting strength. After 13 months in storage, however, it had comparatively little strength. Mortars H-1 and R-2 had only moderate strengths after a storage of 7 and 3 months, respectively. The strength was considerably lower in both cases after longer periods in storage. The strength of those mortars shipped in metal containers, however, was uniformly high after storage from 2 to 5 years.

TABLE I

EFFECT OF STORAGE ON CO_2 CONTENT AND STRENGTH OF MORTARS

Mortar No.	Container	Stored (months)	CO_2 content (%)	Strength (lb./in.²)
B-1	Iron drum	24	0.40	2300
D	" "	65	0.10	2600
F-1	" "	24	0.40	1830
H-1	Sack	7		525
H-1	"	23	1.10	200
R-2	"	3		440
R-2	"	8	0.70	130
Z-1	"	13	1.90	160
Z-1	"	1/4	0.35	2380

The results of carbon dioxide determinations on these materials after storage indicated that the sodium silicate in some had probably been largely converted to sodium carbonate.[7] Visual evidence of the ease with which sodium silicate may be converted is the white efflorescence or fuzz of sodium carbonate which often forms on the face of mortar joints shortly after an installation of firebrick with air-setting mortars.

Although the data are limited, they show that the percentage of CO_2 was significantly greater in the mortars stored in sacks for any considerable time than in those stored in steel drums. In every case in which the CO_2 content was high, the mortar had low strength, as illustrated by brand R (Fig. 4), regardless of the mixing and soaking time.

[7] Vail points out the desirability of metal containers for the storage of sodium silicate because of the absorption of carbon dioxide (see J. G. Vail, Soluble Silicates in Industry, p. 161. Chemical Catalog Co., Inc., 1928; *Ceram. Abs.*, **8** [4] 308 (1929)).

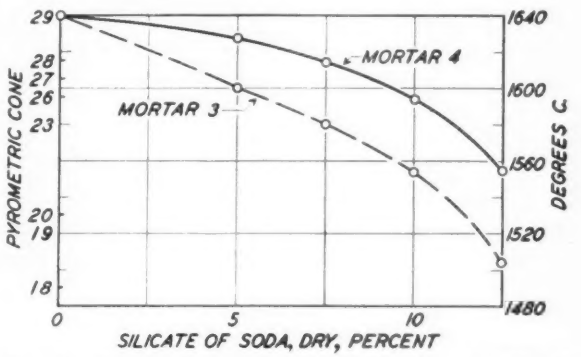

FIG. 5.—The P.C.E. of the 1-hr. mixes of mortars Nos. 3 and 4 (see Fig. 3 for details of mixes).

(6) Pyrometric Cone Equivalents

Figure 5 shows the P.C.E. of the laboratory-prepared mortars, Nos. 3 and 4. They were mixed for 1 hr. and contained varying percentages of sodium silicate added originally in powder form. The P.C.E. of the mortars decreased with increasing amounts of sodium silicate, the rate of decrease being greater the higher the percentage of soda. The mixes containing the silicate of the higher soda-silica ratio were from $1^1/_2$ to 3 cones lower in refractoriness than those containing comparable percentages of silicate of the lower soda-silica ratio.

Although the data are not given, there was a tendency for the majority of the 15-minute mixes to be about one cone lower in refractoriness than those mixed for 1 hr.

IV. Summary

Various properties of a fire clay from Ohio and one from Pennsylvania and of six proprietary brands of air-setting mortars were determined.

For mixtures of (1) water and Ohio clay, (2) Ohio clay and grog, and (3) Ohio clay, grog, and silicate of soda in solution, the strengths after drying first increased and then decreased as water was added to change the consistencies from a very stiff to a somewhat fluid state. At maximum strength, however, these mixtures were far too stiff for troweling. The mix containing the silicate of soda showed increased strength but decreased workability as the time of mixing was increased from 2 to 5 hr.

Mortars were prepared, using the Pennsylvania fire clay with varying percentages of dry sodium silicate and water, to produce a troweling consistency. Two silicates with soda-silica ratios of 1:2 and 1:3.2 were used. The clay without sodium silicate had a dry strength of about 100 lb. per sq. in. Additions of 5 and 12.5%, by weight, of the sodium silicate with the soda-silica ratio of 1:2 increased the strength to 600 and to 2500 lb. per sq. in., respectively. Additions up to 7.5% of the silicate of the 1:3.2 soda-silica ratio produced comparatively small increases in strength to about 500 lb. per sq. in. Above 7.5%, however, the mixes compared favorably in strength with those containing the more alkaline silicate.

The P.C.E. of the mixes containing the dry sodium silicate of the 1:2 soda-silica ratio ranged from $1^1/_2$ to 3 cones below those containing equal percentages of the silicate of the 1:3.2 soda-silica ratio.

The results of strength tests made on three brands of air-setting mortars after mixing for various periods up to 20 hr., with intermittent overnight soaking and maintaining the water about constant, showed distinct differences in strength with various mixing times. One had maximum strength after 5 hr. of mixing; one decreased in strength after the first $^1/_2$ hr., although the decrease was negligible; and one was weakest after 2 hr. and strongest after 10 hr. of mixing.

Specimens made from mortars stored in sealed iron drums were relatively strong after storage from 2 to 5 years, whereas those specimens prepared from mortars stored in burlap or jute sacks lined with "moisture-proof" paper were weak after only 3 months of storage, and they also contained appreciably more carbonate than the former specimens.

National Bureau of Standards
Washington, D. C.

RECIRCULATING AIR HEATING APPLIED TO CERAMIC DRYING *

By Roy Hummel and Robert Twells

Abstract

The development of special furnace equipment and modern low-sulfur fuels makes it possible to use their products of combustion for drying many types of ware. In recirculating air heating, the fuel is burned in an external heater, and the products of combustion are mixed with air to dilute them to the desired temperature. The hot mixture of gases is recirculated rapidly through the drier by an external fan. Fresh hot gases are added from time to time in sufficient amount to replace a small volume exhausted from the drier stack and to maintain the drier temperature. The application of recirculating air heating to ceramic drying is described.

I. Introduction

Waste heat from furnaces or from exhaust steam is the cheapest source of energy for drying. In ceramic plants where waste heat is not available or not applicable with economy, heat must be generated for the drying processes. The cheapest method, from a standpoint of economy, is the application of the products of combustion directly to the ware being dried.

The use of live steam for low-temperature drying is costly. The rate of heat transfer from steam to air is low and requires a large amount of pipe-coil. The over-all efficiency of the process is seldom more than 30 to 35%.

The indirect application of the products of combustion in the direct-radiation type of drier is the method of combustion drying commonly used in ceramic processes. The heat in this case must pass through the walls of

* Presented at the Forty-First Annual Meeting, The American Ceramic Society, Chicago, Ill., April 19, 1939 (Materials and Equipment Division). Received May 3, 1940.

tubes or tunnels by conduction and then to the ware by radiation and convection. The difficulty of application and the over-all low efficiency may actually make this method more expensive than the use of live steam.

Direct combustion has been used for drying some of the lower grades of ware, but it has not come into general use because of the types of fuel commonly available. Some fuels, high in sulfur, give off combustion gases which tend to corrode metal drier furniture and to discolor the ware when they are applied directly in the moist atmosphere of a drier. Wood, being cleaner than other solid fuels, has been used directly as a fuel in auxiliary furnaces to supplement waste-heat drying. During recent years, there has been a marked development of fuels that are cheap, clean, free from objectionable impurities, and easy to apply and control. Gaseous fuels are especially suitable, and natural gas, practically sulfur-free, is being supplied in many cases.

As a result of the development in fuels, furnaces for heating processes up to 1250° F. have undergone radical changes in design. At the present time, many industries are using products of combustion directly in a wide variety of low-temperature heating operations. Some of these operations are core and mold baking; roasting meats; baking bread; annealing and decorating glass; japan paint lacquer and enamel drying; lithographing; rubber curing; drying insulating varnishes on electrical equipment; and drying paper, food textiles, raw fibers (cotton), various chemicals, porcelain enamels, and clay products.

The process, which is called convection or recirculating air heating, has successfully met conditions of rapid heating, sensitive temperature control, and uniformity of temperature, combined with thermal efficiencies as high as 85 to 95% of the theoretical B.t.u. value of the fuel.

II. Recirculating Air Heating

The principle of recirculating air heating involves the movement of large volumes of heated gases about the object to be heated, recirculating the partially cooled gases once more in closed circuit through the same source of heat and back over the object to be heated. A circulation of sixty changes of furnace atmosphere an hour is not unusual in this method of heating, while adding the equivalent of only five fresh air changes in the same amount of time.

The principle of convection (recirculating air heating) has been widely used in ceramic driers with steam as the heating medium, the coils and circulating fans being located within the structure of the drier. The trend in other industries[1] is to use liquid or gaseous fuels and to locate the circulating fan and source of heat outside of the drier or furnace even when steam is used.

The source of heat is usually a gas-fired heater of high efficiency and rugged construction, burning natural, artificial, or butane gas or their mixtures (Fig. 1). The common practice is to mount one or more direct heaters externally on the furnace to supply products of combustion diluted with heated air directly to the circulating fan. The moisture present in the atmosphere due to combustion is usually so small an amount as to have no effect on drying. The moisture due to combustion in one case is reported to be 1.7% of the absorption capacity of the circulating air.[2]

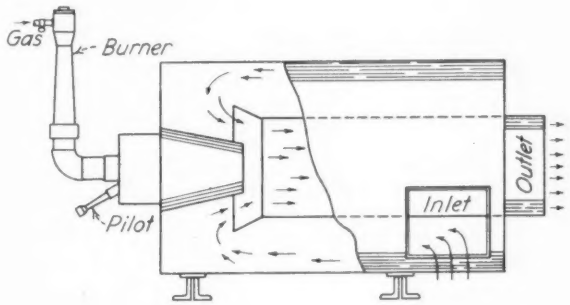

FIG. 1.—Diagrammatic sketch of a gas-fired heater for supplying diluted products of combustion directly to a drier.

In extreme cases where the furnace atmosphere must be absolutely free from combustion gases, an indirect type of exterior heater is used, but the resulting over-all efficiency is reduced to about 55 to 65%.

III. Applications of Recirculating Air Heating to Ceramic Drying

(1) Enamel Drying

Several tunnel and room types of driers in operation utilize recirculating air heating for drying enamels. In the tunnel-type drier, the wet coated parts pass through on a conveyer. In one such installation, air is forced through an indirect or "automobile radiator" heater to ducts in the drier, and a considerable portion of the air is recirculated. Another type of tunnel drier uses a direct heater, wherein the products of combustion are cooled and diluted by the addition of air, and the main portion is recirculated after passing through the drier. At least two such driers use the products of combustion from an external oil-fired heater, the oil used being low in sulfur. Some installations for drying enamels by recirculating air heating utilize the products of combustion from enamel furnaces operating at 1500° to 1600°F. The products of combustion are cooled to about 250°F. by the addition of air before being introduced into the drier. A one-room type drier with an external gas-fired heater is being used to dry ground and cover coats on sheet-steel panels. The drier holds five truckloads of panels. Each truckload is in the drier for 15 minutes at 185°F. The heater burns 310 cu. ft. of 580 B.t.u. artificial city gas per hour at a total cost for gas of $0.097.

[1] L. R. Nourie, "Application of Circulated Air Heating to Industrial Gas Installations." Unpublished address, Eastern Natural Gas Regional Sales Conference, American Gas Assn., Pittsburgh, Pa., March, 1933.

[2] C. F. Mayer, "Moisture Due to Combustion and Its Effect on Drying," *Ind. Heating*, **6** [6] 535, 537–40, 562 (1939); *Ceram. Abs.*, **18** [9] 250 (1939).

(2) Insulator Drying

One drier uses the products of combustion from burning natural gas to dry spark-plug insulator blanks. The drier consists of two chambers, the first being maintained at a lower temperature and a higher humidity for the slow initial drying and the second at a higher temperature and a low humidity for the final drying stage. The wall construction (Fig. 2) is cheap, but it is heavily insulated to conserve heat. Figure 3 shows the operation of the fans and heater. The hot room, fan, and ducts operate as a closed circuit. The fan forces air through ducts in the side of the chamber and withdraws air from a duct at the top (Fig. 4). Some air is constantly being added to the circuit from the heater, but the heater operates only to the extent it is needed to maintain a given temperature, which is set on a thermometer controller in the chamber. The low-temperature room also operates with a separate fan as a closed circuit, bleeding a little heated air from the hot room and exhausting a small volume to the stack. The inlet and outlet dampers are kept nearly closed at all times. The high-capacity fans, operating in closed circuit, circulate the atmosphere in each drier from 25 to 45 times per hour, resulting in rapid and uniform heating.

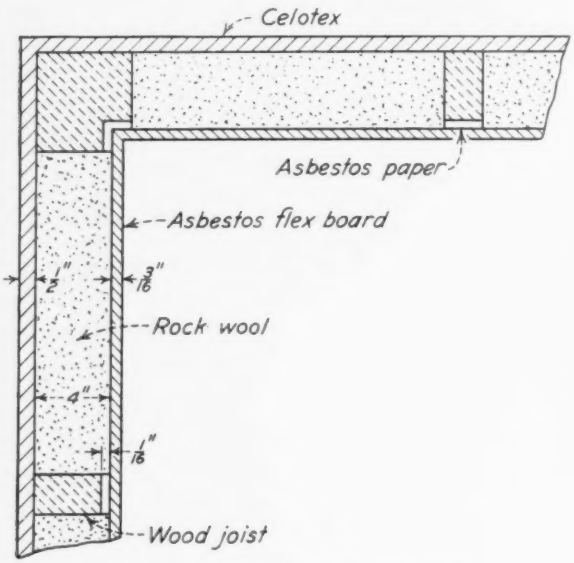

FIG. 2.—Detail of drier wall construction.

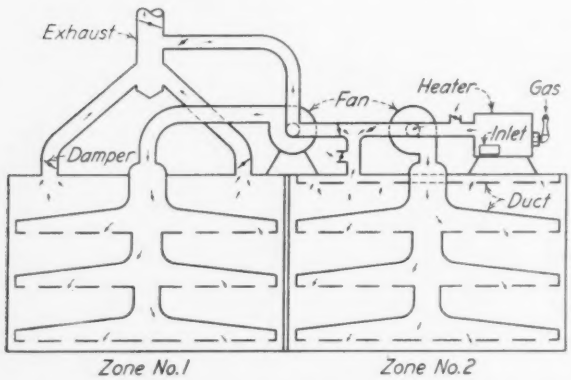

FIG. 3.—Diagrammatic sketch showing the location of the heaters, fans, and ducts and detail of circulation of drier atmosphere.

(3) Construction and Operation Data

Dimensions	Room No. 1		Room No. 2	
	Outside	Inside	Outside	Inside
Length	29 ft. 6 in.	29 ft.	22 ft. 6 in.	22 ft.
Width	17 ft. 6 in.	17 ft.	17 ft. 6 in.	17 ft.
Height	8 ft. 6 in.	7 ft. 10 in.	8 ft. 6 in.	7 ft. 10 in.
Volume	3860 cu. ft.		2930 cu. ft.	

Capacity		
No. of trucks	24	16
No. of blanks	168,000	112,000
Weight of blanks (lb.)	27,500	18,300

Drying cycle

Moisture in ware	(%)
At entrance to drier	14.0
Leaving room No. 1 at end of 24 hr.	2.25
Leaving room No. 2 at end of 24 hr.	0.2 (chalk white)

Heater

Type: Surface combustion A O P 250.

Capacity: 250,000 B.t.u./hr.; 250 cu. ft./hr. of 1000 B.t.u. gas at 6 in. of water pressure.

Fuel: Natural gas from Ohio or West Virginia, sulfur content negligible; B.t.u. value calculated wet, 1038 and dry, 1050; cost, $0.45/1000 cu. ft.

Products of combustion: CO_2 1.063, H_2O 1.991, and N_2 7.82195 equals 10.87595 or the volume in cubic feet at 60°F. obtained from burning 1 cu. ft. of gas.

Condition of system at various points	Temperature (°F.)	Humidity (%)
Gases leaving heater	500–700	
Gases leaving duct in room No. 2	280	
Room No. 2	185	Negligible
Room No. 1 (ware first loaded)	100	68–70
Room No. 1 (at completion of 24 hr. drying)	145	19

Analysis of atmosphere in room No. 2	(%)
CO_2	0.8–1.2
O_2	19.2–20.4
CO	0 0
N_2	Difference

Fans

	Type	R.p.m.	Fan capacity (cu. ft./min.)	Room atmosphere circulates times/hr.
Room No. 1	Clarage No. 11	1370	1620	25.4
Room No. 2	Clarage No. 11	1430	2100	45.3

Cost of operation of drier

Gas	130 cu. ft./hr.	$0.06
Electricity	Fan No. 1 (1¼¢ kw.-hr.)	0.02
Electricity	Fan No. 2 (1¼¢ kw.-hr.)	0.02
Total cost/hr.		$0.10

Safety Equipment: In a gas-operated drier of this type, safety equipment must be adequate and certain in operation. The system must be guarded against

(1) power failures in all circuits, (2) slippage of belt on fans, and (3) failures of fans, of combustion, of gas system, of pilot burner to light, and of temperature control unit to turn off gas at the maximum temperature. Figure 5 shows a sketch of the safety equipment.

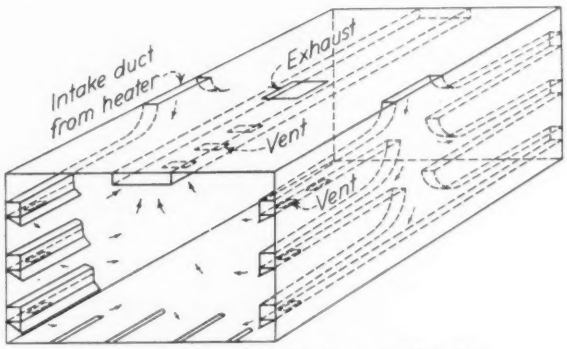

FIG. 4.—Location of the ducts in the drier.

IV. Conclusions

The products of combustion from modern low-sulfur fuels in many cases may be used directly for drying ceramic ware without damage to it or to the drier furniture. The products of combustion mixed with air should be recirculated rapidly through the drier. The high efficiency of this method of heat application in a well-insulated oven will bring about its wider use in applications for temperatures up to 1250°F.

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5. H. C. Weller, "Annealing and Decorating Glass," *ibid.*, **16** [11] 18–20 (1938).

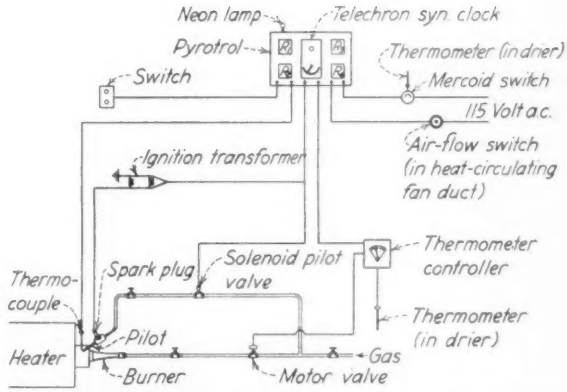

FIG. 5.—Schematic diagram of the safety control equipment.

6. Edward Stephenson, Jr., "Recirculating Air Heating," *ibid.*, **18** [2] 10–12, 17–18 (1939).
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Acknowledgment

The writers are indebted to the Surface Combustion Corporation, Toledo, Ohio, to L. C. Baxter, Northwestern Ohio Natural Gas Co., Toledo, Ohio, and to J. E. Hansen, Ferro Enamel Corp., Cleveland, Ohio, for helpful information and data.

AUTO-LITE SPARK PLUG DIVISION
THE ELECTRIC AUTO-LITE COMPANY
FOSTORIA, OHIO

BRICK-MEASURING DEVICE*

BY GILBERT E. SEIL

ABSTRACT

A brick-measuring device which is rapid and accurate to 0.0005 in. is described.

I. Introduction

Accurate measurements of the dimensions of a brick are needed for the determination of certain constants, such as expansion or shrinkage on removal from the press mold, air drying, oven drying, and firing. These measurements were formerly made with a vernier caliper. Accurate readings required the use of a magnifying glass, it was difficult to place the calipers in proper positions, and the task was tedious and expensive because of the abrasive action of the material on the stops of the calipers. The device described in this article eliminates the difficulties and the inaccuracies of the former method.

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 10, 1940 (Refractories Division). Received July 1, 1940.

II. Description of Apparatus

The apparatus consists of a gauge attached by means of a sliding clamp to an accurately machined stainless steel bar mounted on a plate of the same material. Figure 1 is an assembly drawing of this brick-measuring device.

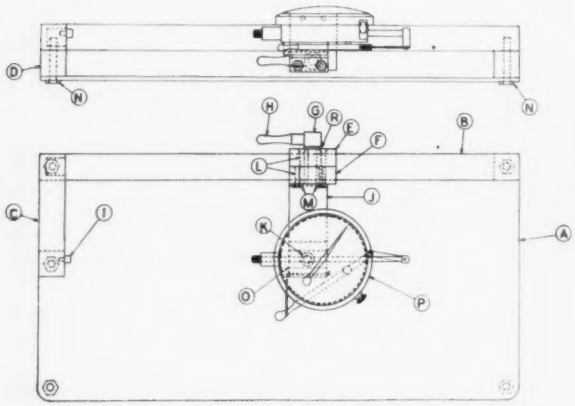


FIG. 1.

The gauge is a dial indicator with fully jeweled bearings, a lifting lever, adjustable bracket, double dial, and telltale. The dial reads from 0 to 100 and each division represents 0.001 in. The telltale reads from 0 to 10 and each division represents 0.1 in. The travel of the indicator contact point is 1 in., and the hands read zero when the contact point is extended $^1/_2$ in.

III. Operation of Gauge

A bar of known length at a set temperature (e.g., 9.000 in., to measure the length of a 9-in. brick) is placed between the contact point of the gauge and the stop on the shorter bar, and the sliding clamp is adjusted to give a zero reading on the gauge. The clamp is tightened and a final adjustment, if necessary to give a zero reading, is made at the dial face, thus establishing the distance between the two contact points. The brick is placed between the points as shown in Fig. 2, the indicator point is allowed to touch the brick, and the dial reading is noted. This reading in inches is added or subtracted from the standard bar length to obtain the length of the brick. The width and thickness of the brick are determined in the same manner, using bars of suitable lengths to establish the position of the sliding clamp.

Standard bars, varying in length from 1 to 9 in., render the device useful for measurement of any object within this dimensional range.

Caution: The brick must be placed squarely against the longer bar and firmly against the stationary stop for each measurement. Any errors are due to improper placement of the brick between the stops or to incorrect readings of the dial.

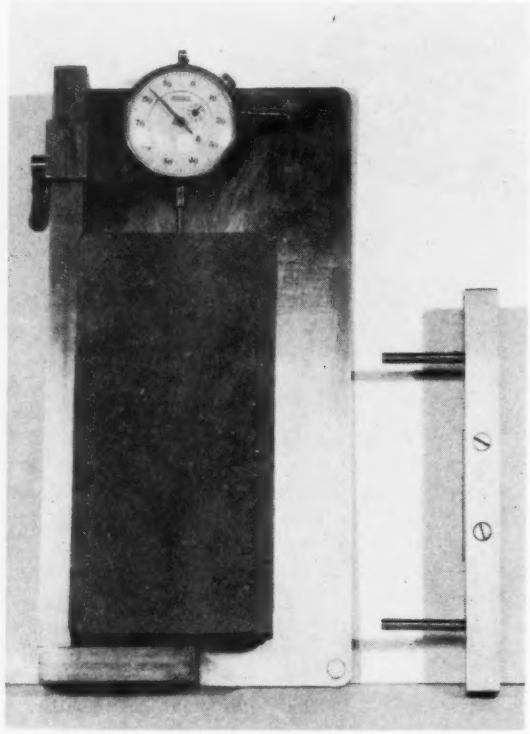


FIG. 2.

IV. Conclusions

(1) The advantage of this instrument lies in its ease of operation and the ability to take accurate readings in one-half the time required in measuring with calipers.

(2) The accuracy[1] of the apparatus is dependent on the accuracy of the standard bar length, the proper placement of the brick between the contact points, and the accuracy of the operator. With a reasonable amount of care, the error on each measurement does not exceed ±0.0005 in.

E. J. LAVINO AND COMPANY
NORRISTOWN, PENNSYLVANIA

[1] *Editorial Comment:* The accuracy of the method depends on the accuracy of the standard bar length, but the change of length of the standard bar with temperature may cause an error greater than the 0.0005 in., which the author states is his accuracy. For example, if the standard bar is steel, a change of 20°F. between summer and winter would change a 9-in. length by 0.0012 in.; if the bar is stainless steel, the change would be 0.0018 in.

A NEW SLAG TESTING FURNACE*

By J. C. McMullen

Abstract

A compact furnace is described for testing the action of slag on a section of a standard 9-in. brick up to temperatures as high as 1600°C. Slag, in the form of rods, 1/2 inch in diameter, is fed automatically so as to melt and drip directly on the test brick. After running down the face of the brick, the slag is caught in sand on the furnace bottom. On completion of the test, the test piece, spent slag, and sand are easily removed, leaving the furnace clean. The controllable conditions are degree and uniformity of temperature, atmosphere, slag composition, rate of slag application, and slag drainage from the sample.

I. Introduction

A number of methods have been used in the past to test the resistance of refractories to slag at elevated temperatures. None of these, however, has met with universal approval. The difficulties encountered in making a slag test are due chiefly to the many factors that must be controlled if the results obtained are to be useful. If a small amount of slag, for instance, is placed on a brick and heated, the composition of the slag changes during the test because of the solution of the refractory. Thus, theoretically at least, for only a few moments at the beginning of the test is the composition of the slag known. When a large quantity of slag is used, the problem of finding refractory containers that will not be attacked must be considered. A study of fusion temperatures of cones made of slag-refractory mixtures gives a qualitative test in which such factors as the porosity, particle size, and other structural properties of the refractory are disregarded. The method whereby slag is impinged on the face of refractories, either through the burner or by an auxiliary air blast, is more nearly simulative of service conditions. Although this method gives a source of fresh slag at all times, there are several objectionable features, such as loss of slag as dust through the stack, the necessity of frequent rebuilding because of erosion to the furnace, and the high cost of operation owing to the amount of fuel and number of test brick necessary for each run.

The numerous methods of testing the action of slag on refractories which have been used are reviewed in three published bibliographies. An article by Ferguson[1] in 1928 summarized the work published since the beginning of laboratory slag testing in 1901. A later paper by Simpson[2] in 1932 reviews and classifies the literature to that date, and in 1937, Dodd,[3] after discussing methods used by different investigators, concluded that the chief difficulty encountered in laboratory slag tests is in the reproduction in the laboratory of actual working conditions, or, conversely, the quantitative measurement of results obtained. These bibliographies furnish a comprehensive picture of the status of slag-test methods and apparatus.

II. Development of Test

(1) Requirements of Slag Test

The slag furnace and method of testing described herein is an effort to produce a universal test in which the following conditions may be carefully controlled: (*a*) degree and uniformity of temperature, (*b*) rate of heating and cooling, (*c*) atmosphere, (*d*) slag composition during the test, (*e*) slag viscosity during the test, (*f*) rate of slag application, and (*g*) complete slag drainage from the sample.

By keeping these factors under control, it is believed that conditions to which any refractory is subjected in service may be simulated in the laboratory. Thus, by a simple test, data may be obtained from which to predict whether or not a particular refractory will be suitable for a particular job.

(2) Features of New Furnace

Recent improvements in materials for furnace construction have made it possible to design a furnace which seems to meet the requirements as set forth. By heating electrically with nonmetallic elements, temperatures up to 1600°C. may be obtained and easily controlled, and any heating and cooling schedule can be accurately repeated when it is once established. The test chamber, moreover, is kept free from combustion products, thus permitting the introduction of other gases to produce any atmosphere desired. To keep the slag from coming in contact with and contaminating the furnace or the heating elements, it is introduced in the form of rods rather than by dropping or blowing it in.

In order to form the desired rods, finely ground slag is mixed with a temporary binder and water and is then extruded into paper tubes, 1/2 inch in diameter and 14 in. long. When dry, these tubes are fed automatically into the furnace at a predetermined rate through a fused-cast refractory tube. The slag melts as it leaves the tube and drips onto a test piece inclined at an angle of 30 degrees. The active slag runs down

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 10, 1940 (Refractories Division). Received April 26, 1940.

[1] R. F. Ferguson, "Review of Literature on Laboratory Slag Tests for Refractories," *Jour. Amer. Ceram. Soc.*, **11** [2] 90–98 (1928).

[2] H. E. Simpson, "Classified Review of Refractory Slag Tests," *ibid.*, **15** [10] 536–44 (1932).

[3] A. E. Dodd, "Action of Slags on Refractories and Some Methods of Testing," *Trans. Ceram. Soc.* [England], **36** [2] 63–73 (1937); *Ceram. Abs.*, **16** [9] 275 (1937).

the face of the test piece, corroding as it goes, and finally drips into sand on the furnace floor, thus keeping the furnace itself clean throughout the run. More than sixty tests have been made with the present furnace, and at no time has the slag come in contact with the walls or the heating elements. When the test is completed, the sand, spent slag, and test brick are removed through a trap door at the bottom of the furnace.

III. Design of Furnace

Figure 1 shows the details of furnace construction. The size is such that it will accommodate a test piece which can be cut from a standard 9-in. brick. In the 9- by 9- by 10-in. chamber are located the slag feeder tube, the tube for the thermocouple or optical pyrometer sighting, the test piece, and the support for the test piece. Figure 2 shows the furnace and the feeder mechanism.

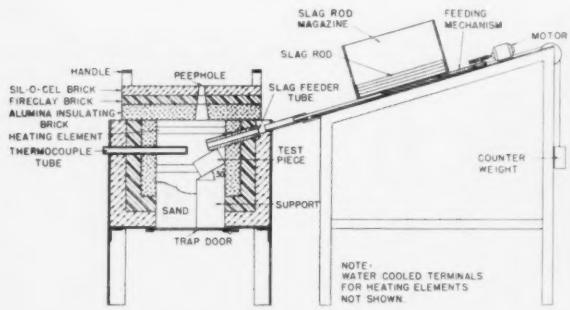


FIG. 1.—Furnace construction.

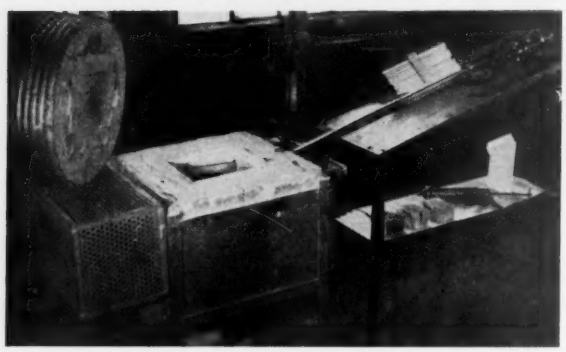


FIG. 2.—Furnace and feeder mechanism.

The walls of the furnace consist of $2^1/_2$-in. alumina insulating brick, backed up with $2^1/_2$-in. insulating firebrick and $2^1/_2$-in. Sil-O-Cel brick, all laid up in a high-grade silicate cement. The shell is f ned of No. 10 gauge sheet iron, held in place by ?- by $^1/_4$-in. angle-iron frame. The construc e furnace cover is similar to that of the furi .. A peephole in the cover and one in the front side of the furnace enable the operator to observe the test specimen as the test proceeds. The bottom portion of the furnace is filled with sand which holds the support brick for the test piece in place and also catches the spent slag. A trap door of $^1/_4$-in. iron completes the bottom of the furnace and permits the easy removal of the sand, slag, and test piece and its support when the test is completed. This door can be opened as soon as the temperature drops sufficiently to freeze the spent slag. An alternate bottom construction may be used, whereby tests can be made over a long period of time and the slag can be drained continuously. The bottom in this case can be made of brick, similar in composition to that being tested, and built in the form of a depression having a hole in the center to permit continuous slag drainage.

The tests in most cases have been run for one or two hours only because during this time a measurable amount of erosion has taken place. With the sand bottom as shown in Fig. 1, about 3 lb. of slag can be collected before its level rises high enough to attack the furnace walls.

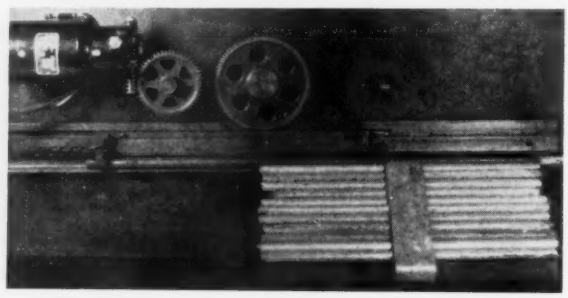


FIG. 3.—Slag-feeder mechanism.

The slag-feeding mechanism delivers the slag rods automatically at any predetermined rate, from $^1/_4$ to 2 in. per minute. This amounts to about $2^1/_2$ lb. of slag in a two-hour test at top speed. Figure 3 shows the slag-feeder mechanism at the point where the pusher rod is returning, after having finished pushing one rod of slag forward. When the pusher rod has returned completely, another slag rod drops in place and moves forward immediately.

IV. Operation of Furnace

(1) Power

The present furnace is supplied from a tap transformer, having a range of 55 to 110 volts in 1-volt steps. Heating elements are available, however, which would permit the use of a 110-volt line with a make-break contact or rheostat arrangement. A power input of about 10 kw. is required to maintain the maximum temperature of 1600°C. Figure 4 shows a typical heating schedule for testing a fire-clay refractory.

(2) Preparing the Sample

A piece, $3^1/_2$ in. long, cut from a 9-in. brick, forms the test piece, which is $2^1/_2$ by $3^1/_2$ by $4^1/_2$ in. To support this piece in the furnace, one end of a high-alumina fire-clay brick is cut at an angle of 30 degrees (Fig. 1). This type of support has been found satisfactory for all tests except those made on basic mixes. A magnesia

brick in this case may be used as a support. The test piece is cemented to the support with a suitable material, such as a silicate cement, refractory clay, or caustic magnesia, depending on the composition of the test specimen. After it is dried, it is ready to place in the furnace.

(3) Placing Test Support and Sample

The furnace cover and thermocouple tubes are removed to allow the sample to be placed. An inch or two of sand is poured in the furnace, and the support brick and sample are placed on this directly under the fused-cast slag feeder tube. When this is done, more sand is poured around the support and cupped out by hand to form a depression to catch the molten slag that accumulates during the test. The thermocouple tube and top cover are then replaced, and the furnace is ready for heating up.

(4) Slag Rods

Each type of slag works differently, and methods had to be worked out for each as the case required. For example, the basic open-hearth furnace slag, even when it was finely milled, did not have sufficient plasticity for extrusion. This difficulty was overcome by adding 2% of lime to the slag. As this slag already contained a large percentage of lime, the other components, such as Al_2O_3, MgO, SiO_2, and Fe_2O_3, were also added to restore the proportion of the constituents originally present in the slag. Hydraulic setting materials, such as Portland cement, are made into rods by pouring into rolled tubes of waxed paper; iron tubes are not necessary. The paper is left on the rods and burns off as the rod enters the furnace, thus admitting few or no combustion products into the furnace. In the case of glass, $\frac{1}{2}$-in. rods of numerous compositions may be purchased or made to order.

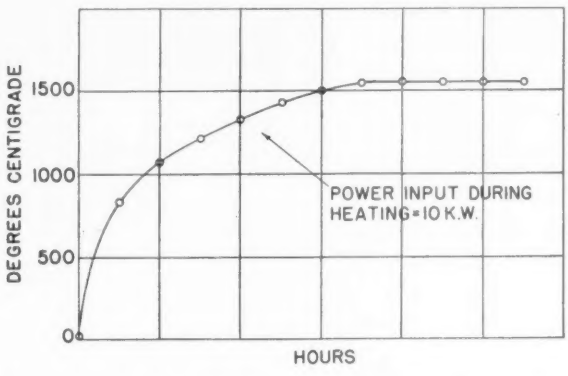


FIG. 4.—Typical heating schedule for fire-clay refractories test.

(5) Running a Test

The furnace is heated at a desired rate and held at the temperature chosen. The slag rods, cut to the proper length, are put into the feeder, and the feeding mechanism is started. Little attention is necessary during the test, and there is ample opportunity for the operator to watch the action of the slag through a dark glass. To obtain the best results, the slag should be fed sufficiently fast so that it starts to melt just as it leaves the feeder tube above the test piece. If it melts sooner, this tube becomes unnecessarily eroded and its useful life is shortened. The last slag rod is followed up by a dummy, consisting of a $\frac{1}{2}$-in. diameter wood dowel stick so that the feeder tube will be open for the next test.

(6) Removal of Test Piece

At the end of the test, the temperature is maintained for about five minutes to allow the excess slag to flow from the face of the test piece. The power is then shut off, and when the furnace is sufficiently cool, the trap door at the bottom of the furnace is opened, and the sand, the spent slag and support, and the test piece are removed.

V. Results

The degree of erosion is determined by measuring the depth of the trough which the slag has cut in the test piece. The penetration can be found by breaking the test piece across the slagged portion. Owing to the short time the furnace has been in use, no attempt has been made to correlate the results with the behavior of duplicate refractories in service. The results shown by a number of samples, however, indicate that such a correlation is to be expected.

FIG. 5.—Test brick.

Figure 5 shows several of the brick tested, and a description of these brick is given in Table I.

TABLE I

	Test piece	Slag	Temp. (°C.)	Time (hr.)	Depth of erosion (cm.)
(1)	Fire clay	65 soda ash 35 flint	1400	2	0.08
(2)	" "	Soda-lime glass	1500	2	0.83
(3)	" "	Portland cement	1600	1	6.44
(4)	Commercial glass tank block	Soda-lime glass	1550	2	0.14
(5)	Duplicate tank blocks	Soda-lime glass	1550	2	0.14

Other materials that have been used successfully as slags in this furnace are commercial soda-lime glass rod, raw soda-lime glass batch, basic open-hearth slag, Portland cement, synthetic coal-ash slag, and iron rod.

VI. Conclusions

The slag test described has the following advantages: (1) it has a wide range of applicability, yet it is economical, rapid, and easy, and the apparatus required is compact; (2) it permits the use of a specimen which retains the original surface and physical properties of the brick; (3) it gives reproducible results; and (4) it makes possible the testing of slag resistance under conditions controlled with respect to temperature, atmosphere, slag composition, slag viscosity, rate of flow of slag, and complete removal of slag.

The Carborundum Company
Niagara Falls, New York

REFRACTORY LIFE IN ELECTRIC ARC MELTING OF STEEL AND ALLOYS*

By J. H. Chivers

Abstract

A discussion is presented of (1) the types of refractories used in an electric arc-melting furnace, (2) the furnace construction, (3) the effect of voltage variations and of slag composition, and (4) the furnace shell construction. The effect of voltage variations on lining life is important, and the use of sillimanite rings at the electrode openings is helpful in some furnaces.

I. Introduction

(1) Refractories Used

The type of lining used in an electric furnace depends on whether or not the slag (1) is high in silica (acid practice) or (2) carries excess calcium oxide (basic practice). In acid practice, the bottom and side walls are of silica brick with a monolithic hearth of sand or ground ganister. In basic practice, the bottom is built with magnesite brick up to two or more courses above the foreplate and the side walls are built with silica brick or, in some cases, with Metalkase magnesite brick. The furnace hearth consists of a sintered basic material, dead calcined magnesite, or double calcined dolomite. In both acid and basic practice, silica-brick roofs are used most extensively because of their strength and rigidity at high temperatures.

II. Furnace Construction

(1) Bottom

The bottom should be laid very tight to prevent metal cutting through the monolithic hearth. The brick in the side walls should either be laid loose or with expansion joints to allow about $^3/_{16}$ inch per foot of expansion.

(2) Roof

On continuous operation, the roof has an up-and-down motion from one heat to another, owing to contraction and expansion, which causes some spalling of the silica brick. One of the most important factors in the construction of the roof to lessen spalling is to have the proper pitch for any given diameter.

Superduty fire-clay brick are used to advantage when the life of silica roofs is reduced by spalling to relatively few intermittent heats. Under these conditions, the use of fire-clay roofs may result in lower cost per ton of metal melted regardless of first costs.

Superduty fire-clay brick have a higher melting point (about 3185°F.) than silica brick (3075°F.). They are used to good advantage where very high temperatures are required for refining and where contamination of the slag by the drip from silica roofs is objectionable.

(3) Side Walls

To balance the life of the side walls with that of the remainder of the furnace so as to reduce the frequency of troublesome minor repairs, the use of Metalkase magnesite brick of the improved type in the side walls or in the back walls only and of chemically bonded, unfired, magnesite brick in door jambs and arches is frequently good practice in basic furnaces. In some instances, periclase brick are used successfully between the magnesite brick in the bottom and the silica brick in the upper side walls. The periclase type of brick is higher in magnesia and lower in iron oxide by about 5% than regular magnesite brick.

III. Chrome Brick

Chrome brick are not used extensively in electric arc furnaces because, under the highly reducing conditions of the finishing slag, any drip or spall causes chrome to be precipitated into the metal bath. This cannot be controlled, and for this reason chrome brick has not been used successfully in electric furnace construction except perhaps where high chrome steels are being melted exclusively. At present, there are at least three 10-ton units, lined with chrome brick throughout, with clay roofs for making chrome steels.

IV. Sillimanite for Roofs

Small furnaces with a capacity of about one ton, using sillimanite monolithic roofs, are being success-

* Presented at the Autumn Meeting, Refractories Division, Conneaut Lake, Pa., September 9, 1939. Received September 26, 1939.

fully operated. This product is expensive, but the increased life more than compensates for the high initial cost.

V. Carbon Block

Carbon block linings have been experimented with, and this type of lining may be used more extensively in the future.

VI. Proper Voltage Essential to Refractory Life

One of the main requisites for securing low refractory cost in the electric furnace is the use of the proper voltage for each size of furnace. The higher the voltage, other things remaining equal, the higher will be the refractory cost.

Electric furnaces generally are from 1 to 10 tons in size, but furnaces up to 100-ton capacity have been operated successfully. Ordinarily, the larger the furnace, the higher will be the voltage used, but it is not possible to correlate voltage with furnace size because different operators use varying amounts of voltage and try to compensate for higher voltage by the use of special refractories and special slags.

On the 10-ton furnace, for example, the voltage most generally used on the high tap ranges from 150 to 200; on the intermediate tap it ranges from 115 to 140; and on the low tap, from 85 to 100. The writer prefers voltages of 180, 135, and 95. The method of using these voltages is to start the operation on the intermediate tap and switch to the high-voltage tap as soon as the arc is buried at the beginning of the melt. This high tap remains until a minimum amount of scrap is left hanging on the banks around the edge of the furnace, at which time a transfer is made back to the intermediate tap and from there to the low-voltage tap for the refining period. If the charge is started on its melt with the high-voltage switch, the refractory life will be decreased because the long arc with this voltage causes too great intensity of heat at localized portions closest to the area of this arc. This same thing is true if the high voltage is left for too long a period after the charge is completely melted.

The use of an extremely high voltage on an electric furnace, in the writer's estimation, is of no particular value. In this type of melting, heat is caused (1) by resistance offered to the passage of current through the scrap and (2) by radiation from the arc. If lower voltages are employed with correspondingly higher amperages, the same number of electrical melting units result, thereby permitting the furnace to remain on the high tap for a longer period and decreasing the time for melting. This refers to voltages on the high and intermediate taps, and these taps are used only during the melting-down period. The low-voltage tap is used universally for the reducing periods. The normal period required for melting a 10-ton heat in the modern electric furnace is 1 to $1^1/_2$ hours. The normal refining period is from 1 to $2^1/_2$ hours. Between these two periods, there is from $^1/_2$ to 1 hour that may be used for any specific purpose desired.

The use of high voltage depends entirely on the amount of power required. Where 10,000 or 12,000 kw. are utilized, higher voltages of course are necessary to get the amount of power into a furnace at sixty cycles; but in all cases, particularly on basic operation, it is desirable to utilize the lowest possible melting voltages commensurate with the power requirements.

VII. Slag Composition Affects Refractory Life

Another important factor in refractory costs is the regulation of the slag composition within the limits permissible with the metallurgy involved. It becomes necessary at times to resort to special slags to secure certain specific chemical and physical requirements. In some instances, refractory cost is sacrificed to produce the desired quality. Under ordinary conditions, a slag should be maintained that will keep the maximum amount of heat in the steel and permit the minimum amount of heat to be dissipated on the side walls and roof. This may be controlled by the furnace operator and requires careful observation during the entire heat.

VIII. Importance of Shell Construction

Furnace shell construction also has an important bearing on refractory life. There are now in operation at least three furnaces of 10-ton and one of 25-ton capacity with cone-shaped shells. From the figures available, the 25-ton installation is showing a decrease of between 25 to 50% on refractory cost. This decrease may be due to the fact that the side walls are farther away from the electric arc and that the sloping wall permits building higher monolithic linings.

Firth Sterling Steel Company
McKeesport, Pennsylvania

THREE-DAY FETE ARRANGED FOR DR. BRASHEAR CENTENNIAL

PROGRAM FOR ONE-HUNDREDTH BIRTHDAY ANNIVERSARY (1840–1940)

Friday, November 22

7:30 P.M.: South Side Community Council Tribute—South High School, 10th and Carson Streets.

Saturday, November 23

2:00 P.M.: Flag Raising—23 Holt Street, Sons of American Revolution.

2:30 P.M. Unveiling of Marker on Old Coalshed Workshop, Pennsylvania Historical Commission.

2:45 P.M.: Dedication of Second Workshop as Museum.

2:00–5:00 P.M.: Open House at all Brashear centers.

Sunday, November 24

3:00 P.M.: Service of Tribute to the Memory of John Alfred Brashear—Soldiers and Sailors Memorial Hall, Fifth Avenue at Bigelow Boulevard.

PAGEANT: "A Tribute to the Man Who Loved the Stars" (Direction of Carnegie Tech Drama School), Nursery School (Brashear Settlement), Children of Blind School, Children of School for the Deaf, High-School Students, University Choir, Amateur Astronomers, and Phoebe Brashear Club.

ADDRESS: "The Man Who Loved the Stars," by C. G. ABBOTT, Director, Smithsonian Institution, Washington, D. C.

Monday, November 25

"BRASHEAR DAY" in all educational institutions and group meetings (Mayor issues Proclamation naming November 25 as Brashear Day).

"CITIZENSHIP": Theme, John A. Brashear—symbolic of a great citizen.

6:30 P.M.: Dinner at William Penn Hotel (Tickets, $2.25).

THEME: "The Lens Maker."

"Star-Spangled Banner," led by CHRISTINE MILLER CLEMSON.

GUESTS OF HONOR AND GREETINGS: G. V. MCCAULEY, Corning Glass Works (Supervisor of molding Pyrex for 200-inch Palomar lens); and EDWARD PANDRAY (Assistant to President of Westinghouse Company that made all fittings for Palomar telescope).

ADDRESS: RUSSELL PORTER, Mt. Palomar Observatory.

MUSIC: Chamber of Commerce Quartet.

Dedication of Late Scientist's Workshop to Open Celebration in Honor of 100th Birthday Anniversary*

A small frame building, the workshop of a humble laborer in the steel mills, will be dedicated on November 23, 1940, to the memory of that workman, John Alfred Brashear, who became a scientist and humanitarian, loved and honored by the world.

The dedication of the little building, now part of the Brashear Settlement, 19 Holt Street, South Side, Pittsburgh, Pennsylvania, will open the three-day celebration of the one-hundredth birthday anniversary of Dr. Brashear. In it will be placed pictures, documents, instruments, and other mementos that tell the story of the life of the mill worker from the days when, in that workshop, he made his first astronomical lens to the years when the world honored him for his scientific work and his city loved him for his gentle kindness. The committee which is planning the city-wide celebration is emphasizing the wide scope of Dr. Brashear's work, which twenty years after his death still influences the civic life of Pittsburgh.

He had a great part in the building of the Allegheny Observatory in Riverview Park, serving as chairman of the committee that promoted the project. He was Acting Chancellor of the University of Pittsburgh and was one of the committee of three which drew up for Andrew Carnegie plans for the founding of the Carnegie Institute of Technology. And it was he who helped Henry C. Frick establish the Frick Educational Commission through which thousands of Pittsburgh teachers have received scholarships. For years he headed that fund.

Because of the deep impression Dr. Brashear left on the educational field in Pittsburgh, the city schools will join in the celebration. R. O. Hughes, director of social studies in the city schools, has written a brief biography of the lensmaker to help the schools plan programs.

Mr. Hughes writes, "Our country has given us many examples of men whose lives began in humble surroundings but whose minds and hearts were made of the stuff that enabled them to become great and to serve their fellowmen. Dr. Brashear became famous in the field of science, in education, and in the realm of culture, but through all his life he kept those fine personal qualities which brought him unlimited love and respect. We must honor him as a great Pittsburgher and a great man."

One of the most interesting of the committees planning the celebration is that of the old friends and admirers of Dr. Brashear. It is headed by Mrs. Joseph W. Marsh. Among the "old friends" of the scientist who have already contributed is Mrs. Andrew Carnegie, whose husband and Dr. Brashear were close friends. Mrs. Carnegie sent $1000 to the committee to be used for painting and repairing the old workshop and house in Holt Street which Dr. Brashear built. Another $1000 gift for the same purpose was received in the name of the late Melissa McKee Carnahan, whose grandfather founded the McKee glass factory on the South Side and helped Dr. Brashear to obtain the glass which he used in making his first lenses.

John A. Brashear†

It is not fiction that thrills us most. The strangest thing in life is truth; the most romantic thing in life is man. So the nearer we approach the truth about a man, the closer we come to romance more strange and thrilling than fiction.

The story of "Uncle John" Brashear, as he was affectionately called by literally thousands, is above all a romance. So is the story of almost any successful man. America, the land where all men are presumably born free and equal, where the immigrant can attain to anything but the Presidency, and the poorest native-born need stop not even at that, America is full of romances. But among them all stands a unique figure, the simple, kindly figure of John Alfred Brashear.

For here was a man who, in an age so commercial and materialistic that success is more often than not measured

* *Pittsburgh Post-Gazette*, September 30, 1940.

† Excerpts from Foreword from John A. Brashear, an Autobiography of a Man Who Loved the Stars. Edited by W. Lucien Scaife; published by the American Society of Mechanical Engineers, New York, N. Y., 1924. 252 pp.

in dollars and cents, remained steadfastly true to an ideal of perfection with utter disregard of material gain or loss; a man who was blessed with a love of beauty which kept him continually striving the while it tempered him into a concrete expression of that love itself. His is a unique figure, not because he fought and won from life success in a chosen work, though he did that nobly, but because life gave her gifts to him so generously.

Talk with any one who knew him and you will hear, not what he did, but what he was. Remarkable, indeed, when you stop to consider that in the making of astronomical lenses and instruments of precision he was the peer of any man of his time, and this not in America alone but in Europe as well. Crusty old scientists came to him first because his genius could aid them in their work; they returned because they loved him. The inexperienced amateur wrote to him hesitatingly for help, and a correspondence ripened into a deep friendship which produced important investigations and discoveries in the scientific world. He had the supreme gift of giving himself, and the world is immeasurably richer because he gave himself so generously. For great as was his genius, far greater was the man.

It is indeed difficult to explain how this simple millwright of Pittsburgh became one of its most distinguished citizens and a figure of international importance. Granted that he was the foremost maker of astronomical lenses of his day and that he was a master in the art of making plane surfaces; granted that early in his career nearly every observatory in America and Europe, as well as some in the Orient, was using apparatus which he had made and that the boundaries of science were being continually widened through the perfection of his work; granted all this and more, yet it does not explain the unusual position which Dr. Brashear occupied the last quarter of a century of his life.

Mechanical genius he certainly had. His numerous technical papers undoubtedly contained valuable contributions to scientific knowledge. But genius of this kind cannot explain why a man without formal education should, in the twentieth century, be chosen Acting Chancellor of a large university or why he should be selected by Andrew Carnegie to have such a large share in the work of making and executing the plans for the Carnegie Institute of Technology. Mechanical genius cannot explain why Henry C. Frick, when he wanted to give several million dollars for educational purposes in Pittsburgh, should have selected John Brashear to handle the fund, a man whose entire life had demonstrated his inability to grapple successfully with financial and business problems. There was a genius other than mechanical which made John Brashear Pennsylvania's "best-loved citizen," the intimate of millionaires and paupers, of scientists, educators, and untutored workmen, the friend of the newsboy, the natural, easy playmate of little blind children. It was the genius of a rare personality.

Uncle John's career, in spite of limited schooling, is an inspiring example of the capacity of the human mind to gain knowledge from every available source and of the human heart to radiate its light to every living creature within its range. He combined the ability to work consistently with a real love for the object of his labor and an unquenchable desire to share it with every one who could be interested in it. His desire for a telescope was as much a yearning to acquaint the whole world with the beauty of the heavens as it was to see it himself. Much as he loved and revered his science of astronomy—and surely no man has ever loved it more—he said and he believed that "the science most worth-while in this world is that of extracting sunlight from behind the clouds and scattering it over the shadowed pathways of our fellow travelers." He loved the stars; their beauty and sublimity fascinated him. But because he believed that "there is nothing that contributes more to the elevating and ennobling of the human and spiritual in man than the sight of some of God's beautiful work," he loved them infinitely better. When, later in life, he undertook to raise funds to build the new Allegheny Observatory he did not rest content until it contained a room where any individual, regardless of race, creed, or color, should be permitted to see and learn of his beloved starry heavens.

It is to the eternal credit of America that, in the year 1920, at the very time when lecturers and writers (particularly those from England) were finding in American civilization a worship and respect for nothing except the commercial and material, a simple millwright in Pittsburgh should have been accorded such honors and homage as are bestowed on few; that a man whose ideals commercialism never lowered should have such public respect paid him as is seldom witnessed in any country. Virtue may be its own reward. After all, why not? Still it is good to see the last years of a worthy life crowned with the honors it so well deserves. It is well to feel that there remains everlastingly in the heart of a man a deep respect for the qualities that a rampant commercialism may attempt to deride.

If those who are interested in the education of American youth want to place before them the inspiration of a modern life of love, work, and service, they will do well to acquaint them with the story of John A. Brashear. For his life, as he has written it, is youth speaking to youth, and unless we who are older have hoarded the spark that keeps age forever young, we shall find ourselves outside the ranks of those who can best appreciate his delightful excursions into the past. Uncle John was all but eighty when they placed his ashes beside those of his wife in a crypt in the Allegheny Observatory, but the soul that passed on to take its place among the elect of the immortals was a youthful soul that maturity and accomplishment had failed to age.

John Alfred Brashear was born in Brownsville, Fayette County, Pennsylvania, November 24, 1840, and died in 1920. With the help of his wife, Phoebe Stewart Brashear, Dr. Brashear started his work as a maker of precision instruments in a shop on the South Side, Pittsburgh, Pennsylvania. Before his death, he was awarded honorary degrees by Princeton University and other institutions and was made an honorary member of many scientific societies throughout the world. In 1915, he was voted, by the people of Pittsburgh, "First Citizen of the City," and Governor Martin Brumbaugh of Pennsylvania added the title of "First Citizen of Pennsylvania." Dr. Brashear moved his shop to the North Side of Pittsburgh in 1880 and perfected the spectroscope for astronomical uses. He was a Trustee of the Western University of Pennsylvania (the

predecessor of the University of Pittsburgh) from 1891 until his death, except for the three years he was Acting Chancellor (1901–1903). The John A. Brashear Company, Ltd., which manufactures astronomical instruments at 2016 Perrysville Avenue is famous. The John A. Brashear House is maintained by the Brashear Association, Inc., at 19 Holt Street, Pittsburgh.

Brashear's First Lens (from Autobiography)*

I had determined to make a telescope and had ordered the glass for it. The next step was to find a suitable place to work in. Instead of building a workshop, I bought from my next-door neighbor a little house, eight and one-half by ten feet, which he had built for a coal house. I designed an engine and purchased a small boiler for it. These I placed in a little shed adjoining the workshop. Then I constructed a bench for a small second-hand lathe I had bought, and we had a pretty fair amateur outfit.

Our glass arrived from New York, and my good wife and I went to work at it with all the zeal and interest of children with a new toy. This was in 1872. Our work was, of course, done in the evenings. At that time I usually got up at about five-thirty in order to get to the mill on time. I would not get home until about six o'clock, often much later if there had been any kind of a breakdown in the mill. When I arrived, I would always find steam raised, the shop immaculately clean, everything in order, and a good supper on the table. After the dishes were washed, Ma would always come out and help me; and we have often worked until twelve and sometimes as late as two o'clock in the morning, although our better judgment would often prompt us to go to bed.

When we began work I was absolutely ignorant of the various processes used in lens-making, but I managed to cut the square disks to circular form and to compute the curves roughly, although I knew nothing about a study of the index of refraction or dispersion of the glass. Many, many trials did we have in those years of grinding and polishing. Just as we would approach a time when we thought we could polish the surface, we would get a scratch on it, and it would have to be done over again. One evening when I had one of the surfaces in pretty good shape to be polished, and by the way, I made the grinding and polishing tools myself, I had the misfortune to drop the crown lens. It broke in two pieces, and broke my heart, as well as my wife's, in a good many hundred pieces!

An English friend of ours who happened to be there at the time of the accident asked for the privilege of replacing the disk. This he kindly did, but it required two months to get it from England. Then the work of getting it into circular form and grinding it to the curves all had to be done again, but it proved to be a very good piece of glass as results showed afterward.

Finally we had the five-inch lens ready for mounting. My brother-in-law, Will Sheets, who was a pattern-maker by trade, made the wooden part of the tube for me. We started to make the lens to be about six feet focus; and while the color correction was very nearly right, it had a very serious over-correction for spherical aberration. So the tube was made nine feet long. I made the patterns for the brass parts of it myself, had them cast, and turned them myself in the old lathe to fit the glass and the draw-tube end.

I shall never forget the night that we mounted this tube temporarily in our room that looked to the south, stuck the telescope out the open window, and pointed it to the planet Saturn, which was then in very good position for observing. For three years we had labored lovingly at our task, and now we were to enjoy the fruits of our labor. Although the spherical aberration was barely corrected, yet the view that I had of the planet that night is pictured vividly in my mind today, as is that first view that I had of the same planet in the little telescope belonging to Squire Wampler, through which I had my first view of the heavens in old Brownsville. After my wife and I had enenjoyed the sight, we could not rest until we had called in some of the neighbors, and while it was anything but the perfect glass that later studies told us was absolutely necessary if we were to have the kind of instrument that would come up to the standard, nevertheless, we had some very interesting views of the moon and other objects that did not demand such perfection in the glass as the images of the stars.

Our next job was to construct a mounting for the telescope. This did not take very long, as I found an iron column at McIntosh & Hemphill's Works, near the mill. The equatorial parts were made by my own hands; and a large opening was cut in the roof of our cottage so that we could command a fairly good portion of the heavens. But we had to wait for the stars, planets, and moon to come to us, which we were willing to do.

I had now, in the spring of 1876, come to a place in my work and studies, where I plucked up courage to write to Professor Samuel Pierpont Langley, who had charge of the Allegheny Observatory, asking permission to bring the object glass to the Observatory that he might inspect it and perhaps give me advice about further improving it. I received a gracious reply from him, suggesting a night on which I should call at the Observatory to see him. I immediately prepared for this visit, and I must confess I was greatly excited at the prospect of having one of my dreams come true. How many times, as I lay out on the cinder banks by the riverside after the mills had stopped running, studying the stars when the smoke had cleared away, I had dreamed of the distant day when I might see the heavens through the telescope that I had heard had been erected in the Allegheny Observatory! Many and many a Saturday afternoon I had climbed to the top of "Coal Hill" just to look over at the dome of that observatory—to look and to dream. For not only did I desire the privilege of seeing the beauties of the heavens myself; I dreamed of a day when all mankind, every boy and girl, might have that privilege, too.

There were no cars running at that time out Perrysville Avenue to the Old Observatory near the present Langley Avenue—indeed there were none for many years afterward —and I had the misfortune to lose my way. But at last I arrived at the door of the Observatory, rang the bell, and was ushered into the presence of the man whose friendship I enjoyed from that night to the end of his life.

As he took the lens in his hands and scrutinized its polish and general make-up, I stood trembling before him. At last (and to me, at least, it was a long time coming) he

* *Loc. cit.*, pp. 32–37.

said, "Mr. 'Brazier,' you have done very well"; and then he asked me the character of the curves. When I had told him, he suggested that I should have had an easier task had I made them after the general plan used by the Clarks (Alvan Clark and his sons, possibly the foremost makers of optical surfaces of that day). He asked me if I had any books on the subject of telescope construction, and on my replying in the negative, he went to his private collection of books and brought me a copy of Dr. Draper's work on The Construction of a Silvered-Glass Telescope and Its Use in Celestial Photography. He told me to keep it as long as I wished; but as he valued it very highly, he asked me to be sure to return it to him.

I learned from him that evening that he and his brother John, a professor of chemistry, whose friendship I was happy in acquiring later on, had made a six-inch reflecting telescope in the barn at their father's home; and I could see that he appreciated the difficulties we had encountered in making the five-inch object glass.

Fortunately for me, it was a clear night, and Professor Langley asked me if I would like to have a look in the thirteen-inch telescope of the Observatory. At last I was to have the fulfillment of the wish I had so long cherished!

The planet Saturn was still in good position for observing. The thirteen-inch refracting telescope was placed upon the beautiful planet, the clockwork started, and I had my third view of the queen of all the objects in the heavens. Wonderful! Could I ever make a telescope that would show its ring system, its belts, its satellites, like that?

At first I felt a sort of discouragement when I contrasted my view in this masterpiece with that in our own telescope, but the feeling did not last long, and as I bade my new-found friend good night, I went away with a grateful heart and with a new incentive and a higher ideal before me.

How I devoured the pages of the book he loaned me! Yes, I think it was read through before I slept any that night, as it was Saturday night and I could sleep longer on Sunday mornings.

Before I finished reading the book, I had decided not to go any further in the correction of the five-inch lens. Until my talk with Professor Langley that night, I had not known how much simpler it was to make a reflecting telescope, as that did not require high-grade and costly optical glass and had but one surface to be corrected, though that one must be even more accurate than the surfaces or curves of the object glass. So I decided to keep the five-inch lens, as it was, for my observing until we could make the larger-sized reflecting telescope.

Silvering Method Discovered*

I had made quite a number of experiments with various methods of silvering by the early spring of 1878, and at last I found a method, or rather a modification of a method, which I had seen in the *Scientific American*, called Burton's method, by which I succeeded in obtaining most admirable results in silvering mirrors on the front surface, although it was originally intended for back surfaces, looking glasses, etc. So simple, so certain was this method, that I at once sent a communication to the *English Mechanic and World of Science*, describing it in full for the benefit of my amateur friends of whom there were at that time, literally speaking, scores who were trying to make their own reflecting telescopes.

Little did I think at the time that this method would become *the* method and be universally used for front surface mirrors. The formula has been published in perhaps every chemical journal in the world; and although I am writing this note more than forty years after I had the pleasure of giving it to the world, without money and without price, I often have pleasant reminders of the value of my first humble contribution to the makers of reflecting telescopes.

Almost forty years later I stood in the laboratory of the Mount Wilson Observatory, admiring the beautiful silvered surface of the great one hundred-inch reflecting telescope mirror, made by my old-time friend, Professor Ritchey. Expressing my pleasure to him, he replied, "Well, it was silvered by Brashear's process." Many other methods have since been devised; but I know of none more certain and more easily applied. I think we silvered the surface of the great seventy-two-inch mirror for the Dominion Observatory at Victoria, British Columbia—made by Mr. McDowell at our workshops and finished in April, 1918—in just about two hours and thirty minutes, including the operations of cleaning, mixing chemicals, and final polishing of the surface.

Lens Made by John A. Brashear†

Some idea of Dr. Brashear's contribution to modern science may be obtained from a partial list of some of the important instruments, apparatus, and lenses which were completed in his shops.

(1) The spectroscope for the Lick Observatory completed about 1888. James E. Keeler, then at Lick Observatory, made with this instrument his now classic visual studies of the motion of the nebulae in the line of sight, with a mean error of 3.2 kilometers per second.

(2) The spectroscope for the Halstead Observatory used by C. A. Young chiefly in investigating solar spectra. With this intrument, Young observed in 1892 many double lines in the spectra of sunspots, then supposed to be the effect of "reversal" by superposed gaseous layers at different temperatures, but subsequently shown to be caused by magnetic fields.

(3) Special apparatus for Professor Comstock, which enabled him to determine the constant of refraction by comparing stars at great distances apart.

(4) Optical surfaces for Professor A. A. Michelson's first interferometer; and subsequently the optical train for the International Bureau of Paris, to measure the value of the meter in terms of a wave length of light.

(5) The first spectroheliograph to photograph automatically the surface and surroundings of the sun made for Dr. George E. Hale. Its results have been epoch making in the realm of solar photography.

(6) A spectroscope for Professor Keeler who had become Director of the old Allegheny Observatory and wished to continue his photographic study of the motion of the nebulae, stars, and planets in the line of sight. His work was very successful, culminating in his beautiful demonstration of the meteoritic character of Saturn's rings. This instrument has a flat Rowland grating 1.3 by 1.8 inches,

* *Loc. cit.*, pp. 52–53.

† *Loc. cit.*, Appendix, Part II, pp. 245–48.

with 14,438 ruled lines to the inch; and also a train of three prisms of dense flint glass.

(7) The Mill's spectrograph, completed in 1894, for Director W. W. Campbell, of the Lick Observatory, who used it in his extensive stellar spectroscopic investigations, which yielded, among other results, the velocity at which the sun, earth, and other planets are moving toward the constellation of the Lyre.

It is doubtful whether any other stellar spectrograph ever contained prisms more perfect than those made by Dr. Brashear for this instrument. The thousands of sharply defined photographs of stellar spectra obtained with it by Dr. Campbell and his colleagues rendered possible a new and revolutionary attack on the motions of the stars, which has yielded conclusions of the widest significance.

(8) A large star spectroscope for the forty-inch refractor of the Yerkes Observatory to detect motions of stars and nebulae in the line of sight.

(9) A star spectroscope for the United States Naval Observatory; optical equipment of the Bruce spectrograph for the University of Cambridge, England, and for the Cape of Good Hope star spectroscope.

(10) Large universal spectroscopes were supplied to many other observatories, one of the best being that of the Lowell Observatory in Arizona. In the decade following 1890, some of the largest size concave-grating spectroscopes were supplied to West Point Military Academy; Sloane Physical Laboratory; Royal University of Ireland (Trinity), Dublin; Cambridge University, England; University of Turin, Italy; Dr. Houswaldt's Physical Laboratory, Magdeburg, Germany; McGill University, Montreal; and Paris Observatory, Paris, France.

Perhaps nothing better reveals the growth of the Brashear Works than a list of some of the larger telescope objectives and mirrors completed subsequent to 1888.

(11) A 12-inch object glass, Syrian Protestant College, Beirut, Syria.

(12) A 12-inch object glass, University of Illinois, Champaign, Ill.

(13) A 12-inch object glass, Ohio State University, Columbus, Ohio.

(14) Two 12-inch object glasses for Kenwood Observatory, Chicago.

(15) A 12-inch object glass for Dudley Observatory, Albany.

(16) A 12-inch object glass, 150 feet focal length, for Mount Wilson Tower Telescope.

(17) A 12-inch object glass for Ladd Observatory, Providence, R. I.

(18) A 15-inch object glass for Yale University, New Haven, Conn.

(19) A 14-inch object glass for a Philadelphia High School, Philadelphia, Pa.

(20) A 16-inch object glass for Carleton College Observatory, Northfield, Minn.

(21) A 15-inch object glass for S. N. Smith's private observatory, Newport News, Va.

(22) A 15-inch object glass, Dominion Astronomical Observatory, Ottawa, Canada.

(23) An 18-inch object glass for Flower Observatory, University of Pennsylvania, Philadelphia, Pa.

(24) A 15-inch object glass for a Philadelphia High School.

(25) A 12-inch object glass for the University of Indiana, Bloomington, Ind.

(26) A 30-inch reflector for the Keeler Memorial, Allegheny Observatory, Pittsburgh, Pa.

(27) A 30-inch plane mirror, Yale University, New Haven, Conn.

(28) A 37-inch Cassegrain telescope for Professor Campbell's expedition to Chile in connection with the Lick researches on the motion of the stars in the line of sight.

(29) A 37-inch parabolic mirror, University of Michigan, Ann Arbor, Mich.

(30) A $19^1/_2$-inch plane and parabolic mirror, Dominion Observatory, Victoria, Canada.

(31) A 20-inch object glass, Chabot Observatory, Oakland, Calif.

(32) A 24-inch object glass, Swarthmore College, Swarthmore, Pa.

(33) The 30-inch object glass of the great Thaw Memorial telescope built by the Brashear Company with especial reference to photograpic work is, for such purpose, more powerful than larger visual instruments and is rendering noteworthy service in systematic stellar photography by a rapid and accurate method developed at the Allegheny Observatory.

The history of this large refracting telescope, a triumph of the optical-instrument maker's art and science, reveals some of the causes of their great cost and of the time required to make them. Owing to the extreme difficulty of obtaining glass disks of the requisite size, free from striae, from inequalities in the density specified, from hygroscopic and other defects—some of which are only discovered after the glass has been polished—the length of time required to complete them cannot be foreseen. In this case, the Brashear Company was able to obtain satisfactory disks only after a period of seventeen years subsequent to placing the first order in Europe.

(34) Among the successful instruments of the Brashear Company, involving its best theoretical and practical resources, are its photographic doublets, whose lenses are constructed according to an original solution of Dr. Charles S. Hastings, which gives a large and flat photographic field of the sky.

They have been sent to various parts of the world and have been instrumental in making numerous discoveries. Dr. Max Wolf, of the University of Heidelberg, has been particularly successful in discovering new asteroids with his sixteen-inch doublet, capturing on one night alone five strangers on each of his two plates. Two cameras are used so that the trails of the asteroids, which are apt to resemble a defect on the photographic plate, may be readily identified by their same relative position among the stars on the two plates. Dr. Wolf has shown his appreciation of his success with this sixteen-inch Brashear doublet by naming two of the many planetoids discovered with it "Alleghenia" and "Pittsburghia," the latter estimated to be about 260,000,000 miles from the earth.

(35) In October, 1913, the Brashear Company was awarded by the Canadian Government the contract for the optical parts of a seventy-two-inch reflecting telescope for the Dominion Observatory at Victoria, British Colum-

bia, the mechanical parts being awarded to the Warner & Swasey Company of Cleveland. Dr. Brashear was then completing his seventy-third year, with public duties sufficient to occupy all of the working hours of younger men. But he entered upon this, his last great optical task, the world's second largest telescope, only exceeded by the Mount Wilson 100-inch reflector, with as great enthusiasm as he had shown in his youth when, after long hours in the rolling mill, he ground and polished his first five-inch lens which he was too poor to buy.

References

(1) F. W. Preston, "John Peate, Maker of the First Big American Telescope Mirror," *Bull. Amer. Ceram. Soc.*, **15** [4] 129–52 (1936).

(2) D. O. Woodbury, Glass Giant of Palomar. Dodd, Mead & Co., New York, N. Y., 1939; *Ceram. Abs.*, **19** [1] 35 (1940).

(3) G. V. McCauley, "Engineering Problems Encountered in Making a 200-Inch Telescope Disk," *Bull. Amer. Ceram. Soc.*, **14** [9] 300–22 (1935).

FORTY-THIRD ANNUAL MEETING THE AMERICAN CERAMIC SOCIETY

BALTIMORE, MARYLAND, MARCH 30 TO APRIL 5, 1941

Walter A. Weldon, Chairman, Baltimore Local Committee

With the announcement of the Baltimore Local Committees, active plans are under way for the Forty-Third Annual Meeting of The American Ceramic Society to be held in Baltimore, Md., March 30 to April 5, 1941. On October 11, the Committees held a meeting with their Chairman, Walter A. Weldon.

Walter A. Weldon

Mr. Weldon is ceramist with the Locke Insulator Corp., Baltimore, Md. He attended the Rochester Antheneum and Mechanics' Institute and Johns Hopkins University. He has been a member of The American Ceramic Society since 1935. He is also a member of the Potters' Round Table of Baltimore and is listed in Who's Who in American Art. He is interested in Chinese ceramic archeology, and much of his work is influenced by the Chinese.

Mr. Weldon has been an exhibitor for years in American museums and abroad. He has a comprehensive library and collection of Chinese ceramic art, which includes a number of historical items of interest to ceramists. Mr. Weldon has lectured on "The Art of the Potter" and "The Origin of Porcelain" for a number of years in the eastern part of the country.

He has worked for years to create a better appreciation of ceramic art in his city, and visitors always find a welcome both to his home in Baltimore and to one of the largest porcelain factories in America.

In *The Bulletin*, May, 1939, p. 185, Mr. Weldon contributed an article entitled, "A Potter Looks at Chinese Antiques," in which he cites some of his experiences in collecting his Chinese artware.

BALTIMORE LOCAL COMMITTEES

Executive Committee

Honorary Chairman: CARL G. HILGENBERG, Carr-Lowrey Glass Co., Baltimore.

Chairman: WALTER A. WELDON, 621 Edgewood St., Baltimore.

Assistant Chairman: JAMES D. TETRICK, Baltimore Enamel & Novelty Co., Baltimore.

Transportation Committee

E. C. GREENSTREET, *Chairman*, Baltimore; and L. E. MONG and ANSEL S. CREAMER, National Bureau of Standards, Washington, D. C.

Entertainment Committee

L. C. ROCHE, *Chairman*, Maryland Glass Corp., Baltimore; JAMES D. TETRICK; ROY A. BLUNT, Buck Glass Co., Baltimore; CLARENCE B. MCCOMAS, Carr-Lowrey Glass Co., Baltimore; H. G. WOLFRAM, Porcelain Enamel & Mfg. Co., Baltimore; and ALFRED N. FINN and T. A. KLINEFELTER, National Bureau of Standards, Washington.

Ladies' Entertainment

MRS. L. C. ROCHE, *Chairman.*

Plant Trips Committee

G. H. SPENCER-STRONG, *Chairman*, Porcelain Enamel & Mfg. Co., Baltimore; W. RONALD LESTER, Maryland Glass Corp., Baltimore; KENNETH SMITH, Severn Clay Co., Baltimore; M. L. BELL, General Refractories Co., Baltimore; R. F. GELLER and HERBERT INSLEY, National Bureau of Standards, Washington; and G. W. MOREY, Geophysical Lab., Washington.

Publicity Committee

LOUIS J. TROSTEL, *Chairman*, General Refractories Co., Baltimore; LYMAN C. ATHY, Porcelain Enamel & Mfg. Co., Baltimore; and RAYMOND A. HEINDL, National Bureau of Standards, Washington.

Exhibits Committee

J. M. GILFILLAN, Locke Insulator Corp., Baltimore; W. RAYMOND SCHLEHR, Carr-Lowrey Glass Co., Baltimore;

Louis C. Roche

KENNETH SMITH; and JOHN W. MCBURNEY and R. T. STULL, National Bureau of Standards, Washington.

Finance Committee

LOUIS J. TROSTEL, *Chairman;* PAUL C. STUFFT, Porcelain Enamel & Mfg. Co., Baltimore; V. V. KELSEY, Dominion Minerals, Inc., Washington; CLARENCE H. HAHNER; and DWIGHT G. MOORE, National Bureau of Standards, Washington.

Meeting Service

PAUL C. STUFFT, *Chairman.*

Baltimore Guide Committee

LYMAN C. ATHY, *Chairman,* and W. RONALD LESTER.

Washington Guide Committee

W. N. HARRISON, *Chairman,* and G. E. F. LUNDELL, National Bureau of Standards, Washington.

DR. ANDREASEN WRITES FROM DENMARK

A. H. M. Andreasen of Copenhagen, Denmark, has again expressed his appreciation of his election in April, 1940, to Honorary Membership in The Society (see *The Bulletin,* **19** [6] 226–27 and [7] 273 (1940)). Dr. Andreasen has written as follows to G. A. Bole of Columbus, Ohio.

"I have just had the great pleasure to receive the message of my election as Honorary Member. I will not make a secret of the fact that it is the first testimony of recognition given to me from a foreign country, and my surprise was so much the higher as I hitherto never have written in American periodicals. Of course the election means a great encouragement to me in a certainly not too encourageable time.

"Especially because the communications between the old and the new world are very reduced, I beg you remember me to my different friends in the U.S.A. I hope my numbers of *The Journal* and *The Bulletin* are stored in The Society, so that they will appear to me later."

IOWA STATE COLLEGE

The members of the Iowa State Student Branch of The American Ceramic Society held their annual fall picnic get-together at Brookside Park in Ames. The high spots of the event were plenty of steak sandwiches and an outline of the year's work by C. M. Dodd, Head of the Ceramic Engineering Department.

This picnic is the first meeting of the year and is held in honor of the new men entering the department so that they may become acquainted with the old members and with the workings of the department.

—GEORGE B. HUGHES, *Corresponding Secretary*

NORTHERN CALIFORNIA SECTION

At the first fall meeting attended by thirty-six members and guests of the Northern California Section, E. G. Petherick of Norton Company answered questions following the showing of a sound picture in color, "Norton Abrasives at Work."

C. L. Barr, Supervising Safety Engineer of the State Compensation Insurance Fund, was present. Mr. Barr, who is conducting the Safety Contest being sponsored by the Northern California Section, reported on the contest to date and discussed some of the problems experienced in maintaining a safety-minded personnel (see the October *Bulletin,* p. 412).

The ten plants which have entered the contest are the California Art Tile Co., the California Pottery Co., N. Clark & Sons, the Stockton Fire Brick Co., Gladding Bros. Mfg. Co., Gladding, McBean & Co., the Myers Ceramic Products Co., the Kraftile Co., the Emeryville Chemical Co., and the Westinghouse Electric & Mfg. Co.

L. H. Duschak of the Department of Mining and Metallurgy, University of California, was introduced by Graham G. Smith, Chairman of the Section Research Committee. Professor Duschak spoke of the work that has been done by his Department in following up the contacts made by Mr. Smith and his committee with a view toward developing a ceramic program at the University. In commenting on the interest of the university group in the subject, Professor Duschak also mentioned some of the obstacles to be overcome. This program will be consistently pushed.

Plans for the annual meeting and Christmas party in December and presentation of a safety trophy and certicates were also discussed.

The meeting was held at the Hotel Coit in Oakland with dinner at 6:30 P.M.

CENTRAL OHIO SECTION

The first in the series of fall meetings for the Central Ohio Section was held on October 2 at Zanesville, Ohio. The meeting started in the afternoon with a conducted tour through the Roseville Pottery, Incorporated, in Zanesville. Through the efforts of Mr. Krause and his associates at this plant, the inspection trip was interesting and was highly appreciated by the group.

In the evening, the group met at the Zane Hotel where dinner was served, followed by an excellent talk by Arthur E. Baggs from the Department of Fine Arts of Ohio State University. Owing to illness, the scheduled speaker, Stewart Leonard, Director of the Zanesville Art Institute, was unable to attend, and Professor Baggs was prevailed on to substitute. Professor Baggs showed two interesting reels of pictures, illustrating various techniques in the use of the potter's wheel and the primitive methods of pottery forming and firing as used by the Indians of the Southwest.

There were sixty persons in attendance at this meeting, with representatives from practically every ceramic plant in this territory; also included in the group were J. L. Carruthers and R. C. Purdy, President and Secretary, respectively, of The American Ceramic Society.

—M. C. SHAW, *Secretary*

PITTSBURGH SECTION

Glass, Today and Tomorrow

The members of the Pittsburgh Section of The American Ceramic Society have been invited as special guests of the Pittsburgh Section of the American Chemical Society. The meeting will be held on Wednesday evening, December 11, at 8:00 P.M., in Carnegie Music Hall, Pittsburgh, Pa. The speaker will be Alexander Silverman of the University of Pittsburgh, whose subject will be "Glass: Today and Tomorrow."

The lecture will be illustrated with exhibits from the Glass Center in the New York World's Fair and from the Glass House in the Town of Tomorrow. A number of industries are preparing special exhibits for the occasion, including lighting, heating, and interior decorating.

The same lecture will be presented in Philadelphia, Pa., Wednesday evening, December 18, in the Franklin Institute.

MISSOURI SCHOOL OF MINES AND METALLURGY

The Student Chapter of The American Ceramic Society at the Missouri School of Mines and Metallurgy held its first meeting of the school year on September 25.

The Chapter will originate a single news sheet with news of student and departmental activities.

Mr. and Mrs. John Wisely, of Kansas City, Mo., formerly connected with the Kansas City Art Institute, were guests. Mr. Wisely is a designer of pottery and various art pieces for the WPA pottery project, located in the Department of Ceramic Engineering at the School of Mines. Miss Eleanor Gibson, the first woman ever enrolled in the ceramic department, was also present.

An interesting talk on labor and manufacturing conditions in the whiteware industry was given by Leonard Stearns, of Boston, Mass., who has come to the Missouri School of Mines as graduate assistant in ceramic engineering. Following graduation from M.I.T., Mr. Stearns worked for several years in whiteware plants around East Liverpool, Ohio.

A general get-together was in order after the meeting, with plenty of eats for all.

—P. G. HEROLD, *Head, Ceramic Engineering Department*

NEW MEMBERS FOR OCTOBER

Corporation

FABRICA DE LADRILLOS INDUSTRIALES Y REFRACTARIOS, S. A., Salvador Odriozola Gómez (voter), Monterrey, N. L., Mexico.

Personal

BOEHM, MILTON A., 1502 River Cove Ave., Tampa, Fla.

BURGER, HARRY L., JR., 811 N. Chamberlain Ave., Chattanooga, Tenn.; machining and polishing of ceramic insulation, American Lava Corp.

BURKE, WILLIAM M., 34 Crescent St., Waltham, Mass.; laboratory assistant, Waltham Grinding Wheel Co.

HINCKLEY, ARTHUR T., Oldbury Electro-Chemical Co., Niagara Falls, N. Y.; chemist.

WATTS, ARTHUR P., 3502 Brentwood Drive, Flint, Mich.; engineer, A C Spark Plug Co.

Student

Iowa State College: A. RICHARD BOERNER and CARL WEST, JR.

New York State College of Ceramics: JOHN S. BREITENSTEIN, WILLIAM F. READ, JOSEPH K. SHAPIRO, and ZENO ZABAWSKY.

Ohio State University: WILLIAM R. PATTON and RALPH ROSE.

Pennsylvania State College: W. GRAYDON EKDAHL.

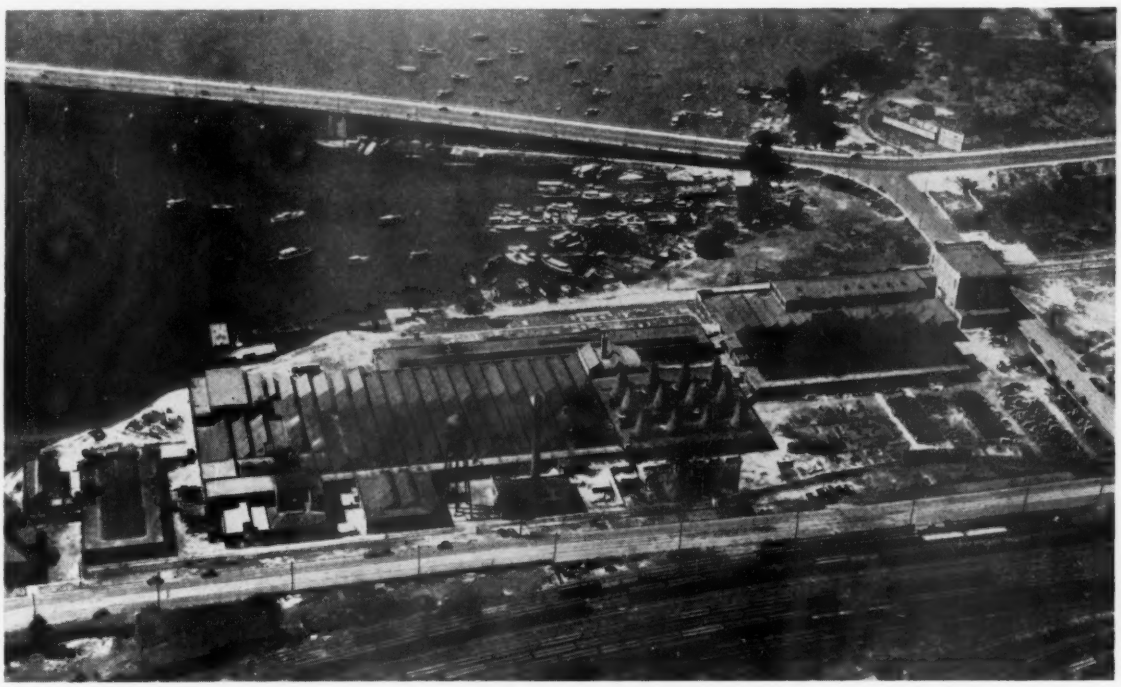
MEMBERSHIP WORKERS' RECORD

Corporation: Office 1.

Personal: G. F. Fichter 1, Donald Hagar 1, and Office 2.

Student: C. R. Amberg 2, C. M. Dodd 2, R. M. Campbell 2, E. C. Henry 1, J. L. Carruthers 1, C. J. Koenig 1, and C. H. Lawson 1.

Grand Total: 15.



Airplane view of the Locke Insulator plant, Baltimore, Md.

EIGHTEEN OF THE EIGHTY PAID PERSONALS NEEDED TO MEET THE ALL-TIME HIGH SCORE WERE OBTAINED IN OCTOBER

We Are Not Quite One-Fourth Way Home to a Real Thanksgiving

Paid Membership Record

Date of Record	Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
	Personal	Corporation				
December 22, 1937	1713	220	12	523	220	2688
December 19, 1938	1815	222	26	589	220	2872
December 19, 1939	1876	237	27	642	220	3002
January 22, 1940	1930	244	23	656	220	3073
February 20, 1940	1972	243	30	669	220	3134
April 17, 1940	1724	241	30	522	220	2737
May 21, 1940	1801	247	27	552	220	2847
June 19, 1940	1839	251	28	556	220	2894
July 18, 1940	1870	254	32	561	220	2937
August 19, 1940	1885	254	31	565	220	2955
September 19, 1940	1892	255	28	572	220	2967
October 21, 1940	1910	256	27	569	220	2982

Yet

Compared with One Year Ago, the October, 1940, Paid Membership Record Betters That of October, 1939, by

85 PERSONALS
21 CORPORATIONS

NOTES AND NEWS

NINTH ANNUAL NATIONAL CERAMIC EXHIBITION

The Ninth Annual National Ceramic Exhibition was held at the Syracuse Museum of Fine Arts, Syracuse, N. Y., from October 13 to November 4. The judges faced a difficult task in choosing from 1000 pieces, representing about three hundred artists from twenty-eight states, a collection which would be truly representative of the present national status of ceramic art.

"Ceramic artists are showing great advances both in scientific knowledge of their medium, which enables them to control it, and in appreciation of its esthetic possibilities," said Reginald H. Poland, chairman of the Jury and director of the San Diego, Calif., Gallery of Fine Arts. "Of course, they are just beginning to realize the extent of those possibilities, and ceramic artists as a group will develop as they broaden their vision and their imagination, realizing also the necessity to advance in scientific knowledge of their medium."

The judges as a group emphasized the advance in maturity in the artists' work, apparently an indication of a general appreciation of improved standards of ceramic design and execution. This recognition of standards, however, does not prevent experiment, often daring in character, into the extension of the possibilities of the clay-and-glaze medium. Ceramic artists are perhaps the most individualistic in America, each working out his own interpretation of the possibilities of his medium and little influenced by anyone else's work.

Excellent pottery in unusual amounts, far surpassing last year, is found in the Exhibition, which led the judges to single out an exceptionally large number of pieces for honorable mention. The pieces are not only artistically interesting but distinctly usable in many types of American homes. The potters are interested in essential form, expressing their ideas through the form, glaze, and texture rather than in surface decoration, which, as an end in itself, has practically disappeared from national ceramic exhibitions.

Prize Awards

Prize awards were given for many different reasons because the entries differed widely in design and execution. The judges tried to recognize the variations both in sculpture and pottery.

The Jury awarded the following prizes and honorable mentions.

(1) Ceramic Sculpture

First Prize ($100): PETER GANINE, Hollywood, Calif., for his monumental piece, "Baby Centaur," designed for outdoor use. An unusually compact, coordinated piece of sculpture, with fine plastic quality and tactile appeal (one must want to touch good ceramic art). Done in unglazed terra cotta of a greenish gray tone, this engaging young centaur on his rockers would fit into many landscapes. Mr. Ganine is well known for his work in other media on the Pacific Coast and has also won prizes for ceramics in exhibitions there (prize given by the American Art Clay Co., Indianapolis, Ind.).

Second Prize ($100): ADOLF ODORFER, Fresno, Calif., for his three figure groups, "Chorus Girls" and "Adeline," in unglazed cream terra cotta, and "Family," in a dark brown glaze. Esthetically realized figure studies, complex in character yet with a unity of line which is pleasing, they represent in sculpture somewhat the complexity of machinery, with a tensity apparent which is characteristic of the modern tempo. A well-handled new note in ceramic sculpture from a young man who was awarded his first mention four years ago (prize given by the Harshaw Chemical Co., Cleveland, Ohio).

Third Prize: PAUL BOGATAY, Ohio State Univ., Columbus, Ohio, for his "Colt" in unglazed red terra cotta, a small figure with great strength and sculptural soundness. Mr. Bogatay's work is well known, and he is a former prize winner in national shows (prize given by B. F. Drakenfeld and Co., New York, N. Y.).

Honorable Mentions in Sculpture: MATHILDE PARMELEE SEWALL, New Haven, Conn., for "Polar Bear," a figure showing great rhythmic vitality and fine modeling in grayish white glaze. Mrs. Sewall won first prize for sculpture in 1937. THELMA FRAZIER WINTER, Cleveland, Ohio, for "Daring Young Man," representative of her fine fluid glazing which gives her work almost the appearance of a liquid medium. A dynamic quality in her circus figures, expressed through color and glazing, shows the artist's appreciation of the loveliness of her material. Mrs. Winter won first prize in sculpture last year. HAZEL SMALL MARTIN, Los Angeles, Calif., for "Squirrel" and "Desert Trio" in unglazed terra cotta, small figures with fine sculptural quality showing interesting use of color.

(2) Pottery

First Prize ($100): MARION LAWRENCE FOSDICK, New York State College of Ceramics, Alfred, N. Y., for a large stoneware bowl. Slip, painted with light brown and gray glaze. "Sound and satisfying" work according to the judges, with the glaze bringing out the inherent quality of the material and enhancing its durability and usefulness. Definitely presents the feeling of "burnt clay," with the decorative qualities in the materials, not added to them (prize given by the Onondaga Pottery Co., Syracuse, N. Y.).

Second Prize ($50): EDWIN and MARY SCHIRER, Durham, N. H., for Mr. Schirer's stoneware bowl, thrown and decorated with fine plastic figures, and Mrs. Schirer's thrown ribbed stoneware vase. Fine form and texture (exhibiting for the first time).

Second Prize ($50): WINIFRED PHILLIPS, Wauwatosa, Wis., for three pieces, tall stoneware jug with a gray body; tall stoneware vase with opalescent lining; and white stoneware bowl with copper-reduced lining (the prize of $100 (divided) was given by the Hanovia Chemical and Manufacturing Co., Newark, N. J.).

The Katherine Q. Payne Award of $50, which is given anonymously for fine hand-thrown pottery, distinguished in shape and glaze and outstanding beyond question, was given to GERTRUD and OTTO NATZLER, Los Angeles, Calif., for a turquoise-gray oval bowl having the unique qualities of the Natzlers' work, fineness of throwing, glazes in Pompeian effect (called "flowing lava") and daring form, which will enhance the usefulness of the piece for certain kinds of flower arrangement.

Honorable Mention (for sustained excellence in pottery): GLEN LUKENS, University of Southern California, Los Angeles, Calif., for two large flat bowls, one in rough-textured black terra cotta and one called "Water of the Sea," turquoise glaze on rough white clay giving the effect of sea water on sand. Designed for use in a patio, they are excellent examples of pieces with great beauty growing out of usefulness.

Honorable Mention (awarded in these terms for the first time for a master model suitable for mass reproduction): ELEANOR PIERCE CUTLER, Ogontz Manor, Philadelphia, Pa., for her large plate, a copper reduction in pinkish coppery tones on a copper standard, entitled "Feast of Solomon."

Honorable Mentions: BEATRICE WOOD, West Hollywood, Calif., for a large plate; good potting and decoration mural in effect. WILLIAM EHRICH, Buffalo, N. Y., large bowl, golden tan terra cotta, glazed inside, and carved figures in "Boar Hunt" design outside. CARLTON

ATHERTON, Columbus, Ohio, stoneware jar with blue decoration and definitely marked pattern; pleasing form and color. CLARA K. NELSON, New York State College of Ceramics, Alfred, N. Y., red clay plate, carved and glazed. KARL MARTZ, Nashville, Ind., "The Golden Belle."

(3) Enamels

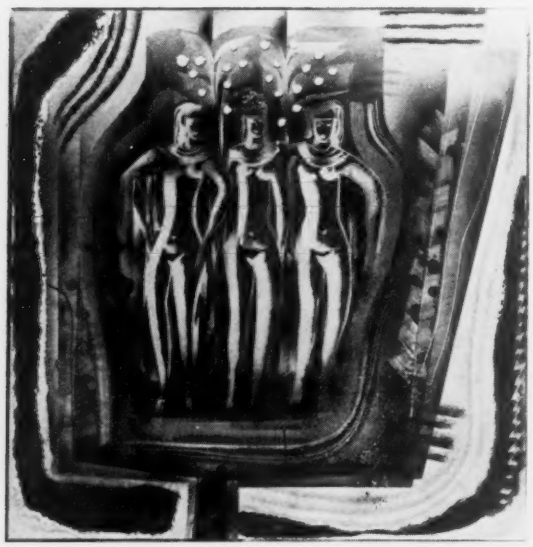
First Prize: H. EDWARD WINTER, Cleveland, Ohio, square panels, enamel on metal (prize given by the Ferro Enamel Corp., Cleveland, Ohio).

First Honorable Mention: KARL DRERUP, Rockville Center, N. Y., panels and bowls.

Honorable Mention: RUSSELL BARNETT AITKEN, New York, N. Y., enamel mural, "Hercules and the Amazons," the largest single unit panel ever fired.

1940–1941 Exhibition Circuit

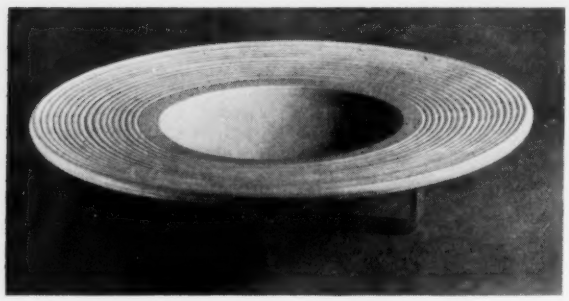
The Ninth National Ceramic Exhibition will be sent to the following museums throughout the 1940–1941 season: November, Memorial Art Gallery, Rochester, N. Y.; December, Albright Art Gallery, Buffalo, N. Y.; January, Flint Institute of Art, Flint, Mich.; February, University of Minnesota, Minneapolis, Minn.; March, Cranbrook Museum, Bloomfield Hills, Mich.; and April, Baltimore Museum of Art, Baltimore, Md., booked by The American Ceramic Society to coincide with the Forty-Third Annual Meeting. A west coast tour is pending for May to September.



Enamels, First Prize: H. Edward Winter, Cleveland, Ohio.

Group: Somewhat bizarre designs, harking back to Victorian lines with jeweled accents, square panels; enamel on metal, "The Dance"; note use of glass beads.

Prize given by the Ferro Enamel Corp., Cleveland, Ohio.



Pottery, Honorable Mention: Eleanor Pierce Cutler, Ogontz Manor, Philadelphia, Pa.

Awarded (in these terms) for the first time; master model suitable for mass reproduction for large plate; copper reproduction in pinkish coppery tones on copper standard entitled, "Feast of Solomon."

Pottery, First Prize: $100 to Marion Lawrence Fosdick, New York State College of Ceramics, Alfred, N. Y.

Large stoneware bowl; slip, painted with light brown and gray glaze; "sound and satisfying" work, with the glaze bringing out the inherent quality of the material and enhancing its durability and usefulness; definitely presents the feeling of "burnt clay," with the decorative qualities in the materials, not added to them. Small bowl by Helen Williams of Syracuse University, Syracuse, N. Y.

Prize given by the Onondaga Pottery Co., Syracuse, N. Y.

Pottery, Second Prize: $50 to Winifred Phillips, Wauwatosa, Wis.

Three pieces, tall stoneware jug, gray body; tall stoneware vase with opalescent lining; and white stoneware bowl with copper-reduced lining; all fine examples of modern functional pottery, with architectural qualities; excellent for use in a modern home, for instance, one de-

signed by Frank Lloyd Wright; glazes again enhance the material and the forms provide the decorative note. Prize ($100, divided) given by Hanovia Chemical and Manufacturing Co., Newark, N. J.

"The Dictator" by Viktor Schreckengost, Cleveland, Ohio.

The Roman Emperor dwarfs the figures of Hitler and Mussolini (right) and Stalin and his sickle (left, not seen in photo); Emperor's feet are resting each side of the British lion; work is characteristic of Schreckengost's sculpture with its humor; one of five pieces by Schreckengost in Exhibition.

Pottery, Second Prize: $50 to Edwin and Mary Schirer of Durham, N. H.

Mr. Schirer, stoneware bowl, thrown and decorated with fine plastic figures; Mrs. Schirer, thrown stoneware vase, ribbed; fine form and texture; both exhibiting for the first time. Prize ($100, divided) given by the Hanovia Chemical and Manufacturing Co., Newark, N. J. *Honorable Mention:* Beatrice Wood, West Hollywood, Calif., for large plate, two stylized clown heads on oyster white background; good potting; decoration, mural in effect.

Pottery, Honorable Mentions: Carlton Atherton, Clara K. Nelson, and Karl Martz.

Mr. Atherton, Ohio State University, Columbus, Ohio: stoneware jar with blue decoration, definitely marked pattern; pleasing form and color.

Miss Nelson, New York State College of Ceramics, Alfred, N. Y.: red clay plate, carved and glazed.

Karl Martz, Nashville, Ind.: "The Golden Belle," wide-rimmed bowl, brown underglaze decoration; yellow "orange-peel" glaze.

NATIONAL COUNCIL FOR ART WEEK NOVEMBER 25 TO DECEMBER 1

Sales Exhibits Planned to Sell American Art to the American Home

Under the leadership of Francis Henry Taylor, Director of the Metropolitan Museum of Art, and of thirty representatives of the foremost art organizations and institutions in the country, forming a National Council, Art Week will be observed November 25 to December 1, 1940, with one thousand exhibitions in as many communities. For a preliminary notice of plans, see *The Bulletin*, October, 1940, p. 414.

Mr. Taylor was requested by the President to act as Chairman of the National Council for Art Week and to name its members. Five federal agencies carrying on nation-wide programs in the arts and in the crafts have joined the President in this request. The National Council will also have the support of state and municipal governments. All artists and craftsmen will be invited to participate in the exhibition of their work, and all those interested in the development and purchase of American arts and crafts will be asked to cooperate.

Encouragement for these displays of community arts and crafts "to inspire the purchase of a piece of American art and crafts for every American home" is given by the great revival of popular interest in American art as noted in the attendance last year of twenty million visitors at art museums and galleries. More than three million persons have been participating in activities of the WPA Community Art Centers and the record crowds have visited the American Art Today exhibitions at the New York World's Fair.

The majority of the thirty million homes in this country represent the potential market for American artists and craftsmen. For the first time on a national scale a broad coordinated effort is being made to invite the public to see and purchase, at moderate prices, original works of art and craft articles passed on by local experts.

NEW YORK SOCIETY OF CERAMIC ARTS SYMPOSIUM ON POTTERY GLAZES

The New York Society of Ceramic Arts held a symposium on Pottery Glazes at the Metropolitan Museum of Art, New York, N. Y., on October 18. One hundred and fifty persons were in attendance.

The following program was presented:

(1) Introductory remarks (briefly covering the origin, history, and classification of glazes) by LAWRENCE E. BARRINGER, President, New York Society of Ceramic Arts.

(2) "Quality in Glazes" by J. PALIN THORLEY, Dept. of Ceramics, Univ. of Pittsburgh, Pittsburgh, Pa.

(3) "Glaze Compositions for Various Ware and Temperatures" by MISS MARION L. FOSDICK, New York State College of Ceramics, Alfred, N. Y.

(4) "Crystalline Glazes" by RICHARD O. LANE, Macklin Co., Detroit, Mich.

(5) "Stoneware Glazes" by THOMAS S. HAILE, London, England.

(6) "Bristol Glazes" by WALTER HOWAT, Tottenville, Staten Island, N. Y.

(7) "Vapor Glazes" by H. G. SCHURECHT, New York State College of Ceramics, Alfred, N. Y.

(8) "Raw Glaze, Tin Enamel, and Underglaze Color Printing" by CHARLES B. UPJOHN, formerly of Columbia University.

(9) "Simple Processes in Glaze and Decoration" by H. AIMEE VOORHEES, Inwood Pottery Studios, New York, N. Y.

Coming Events

The next meeting of the New York Society of Ceramic Arts will be held in the Metropolitan Museum of Art December 5 with Waylande Gregory, who is well known as a ceramic artist, the speaker. Mr. Gregory's topic will be "Creative Achievement in Ceramic Sculpture—Autobiographical."

The Fortieth Annual Exhibition to be sponsored by this organization will be held February 5 to 26, 1941, inclusive, at the National Arts Club, 15 Gramercy Park, New York, N. Y.

—LAWRENCE E. BARRINGER, *President*

ANGELA GREGORY AT NEWCOMB COLLEGE

Miss Angela Gregory has been appointed artist in residence for the 1940–1941 session at the art school of Newcomb College, the women's division of Tulane University.

Miss Gregory, a native of New Orleans, was awarded the degree of Bachelor of Design by Newcomb in 1925, and she received the graduate degree of Master of Arts from Tulane this year. She also studied at the New York School of Fine and Applied Art and the Académie de la Chaumière in Paris. She was engaged from 1926 to 1928 in the private studio of Antoine Bourdelle, noted French sculptor, and has traveled and worked extensively in Italy.

Exhibits of Miss Gregory's architectural sculpture are to be seen at the Louisiana State Capitol Building; the Louisiana State Museum; the Orleans parish courthouse; and Newcomb College, the Hutchinson Memorial Building, the McAlister Auditorium, and the new Howard-Tilton Memorial Library, all on the Tulane campus. Miss Gregory has also executed commissions of a similar kind in other cities in this country and in France, and her work has been represented in over twenty-five exhibitions in various parts of America and abroad.

COMMITTEE ON CERAMIC DATA

The National Research Council has authorized the Committee on Chemical Data for Ceramists of the Division of Chemistry and Chemical Technology of the Council to solicit funds to be used in searching for physical constants of chemical substances of interest in the ceramic and glass fields. Where agreement is lacking, various values will be given; where no information is obtainable, this will be indicated.

The findings of the Committee, after approval by the National Research Council, will be distributed to colleges and universities, government bureaus, and research institutes to urge research to determine or correct data. The report will also be distributed to individuals in the ceramic and glass fields.

Much important material is either erroneous or lacking. The Committee, which consists of Alexander Silverman, Univ. of Pittsburgh, *Chairman;* George W. Morey, Geophysical Laboratory; and Frederick D. Rossini, National Bureau of Standards, will welcome suggestions and cooperation. Contributions of $25 to $100 each are being requested of manufacturers in the ceramic and glass fields. Checks should be made payable to the National Research Council and should be sent to Dr. Silverman.

AIR HYGIENE FOUNDATION ANNUAL MEETING

The fifth annual meeting of the Air Hygiene Foundation, scheduled at Mellon Institute, Pittsburgh, November 12 and 13, will insist that the health of workers is as important as health of soldiers in girding America. Defense production demands the defense of employee health.

Philip Drinker, Department of Industrial Hygiene, Harvard University, will lead a symposium on health safeguards in the mining, mechanical, and chemical industries which bear the brunt of preparedness production; in the first World War, eight to nine men were busy in the mills keeping one soldier supplied at the front.

Other participants in the symposium will include Captain Ernest W. Brown, Senior Medical Officer, Brooklyn Navy Yard (Industrial Hygiene and the Navy in National Defense); Dr. P. A. Neal, National Institute of Health (U. S. Public Health Service in the Defense Program); Dr. Howard W. Haggard, Yale University, noted health writer (Noxious Gases); Dr. Carey P. McCord, of Detroit, Director, Industrial Health Conservancy Laboratories (Health Protection in Electric Welding).

L. Metcalfe Walling, Administrator, Division of Public Contracts, U. S. Labor Department, will outline health requirements on government contracts under the Walsh-Healey Act.

William P. Yant, Research Director, Mine Safety Appliances Co., of Pittsburgh, will talk on the protection of civilians in war time, especially from dangerous gases.

Reports will be made on findings from Foundation-supported researches on industrial health problems by Dr. L. U. Gardner, Director, The Saranac (N. Y.) Laboratory, Dr. Eliot R. Clark, University of Pennsylvania, and Professor Drinker.

Dr. A. J. Lanza of New York, Chairman of the Foundation's Medical Committee, will report on industrial-hygiene developments during the past year.

Dr. W. M. Gafafer, Senior Statistician, U. S. Public Health Service, will make a progress report on the study of "Sick Absenteeism in Industry," which the Foundation is undertaking in collaboration with the Public Health Service and the Association of Industrial Physicians and Surgeons.

CELO KYANITE
UNIFORM QUALITY **DEPENDABLE SUPPLY**
FOR INFORMATION AND SAMPLES WRITE TO
CELO MINES, INCORPORATED
BURNSVILLE, NORTH CAROLINA

T. C. Waters, of Baltimore, member of the Foundation's Legal Committee, will discuss the latest legislation affecting workmen's compensation for occupational disease.

Recent scientific developments in health protection of workers will be reviewed, with emphasis on combating increased hazards from increased production.

BAUSCH & LOMB AND OUR NATIONAL DEFENSE

Defending its eighty-seven year record on national defense, the Bausch & Lomb Optical Co., Rochester, N. Y., largest maker of military optical instruments, has issued a book containing laudatory letters from Secretaries Stimson and Knox of the War and Navy Departments. It refutes attacks on the company's loyalty and patriotism, engendered by the indictment which charged restraint of trade in military optical instruments.

Stimson said, "The relations between Bausch & Lomb and the War Department, extending over a long period of years, have been most satisfactory from every standpoint. At this critical time, the War Department has complete confidence in your company for excellence of workmanship, productive ability, and patriotic cooperation."

Although the case was settled in July by common consent, recurrent attacks accusing the company and its officers of Nazi sympathies and ascribing sinister motives have continued, the statement asserts.

In the opinion of high military authorities, the agreement between Bausch & Lomb and Zeiss, made in 1921, was beneficial to the armed services of the United States. "The flow of engineering services was all from Germany" and not from the United States.

"The Zeiss relationship had been unsatisfactory since 1933, and when war broke out in Europe the American company notified Zeiss that it considered the contract suspended. Since then it has withheld royalties.

"The contract has had no effect on deliveries to the Army and Navy, nor has Zeiss ever had a voice in the determination of prices charged the Army and Navy for military optical instruments manufactured by Bausch & Lomb."

Denying that the contract had resulted in a monopoly or created exorbitant prices, the company asserted that prices, for the most part, were the result of vigorous competitive bidding. "Over a nineteen-year period, our military division has shown a small but actual net loss."

Outlining its services in previous wars, the company said it had broken a foreign monopoly on optical glass during World War I and has persisted in further development of its research and facilities, although this material could have been imported at lower costs from abroad.

Asserting that it is wholly American in ownership, management, and control, the company said that its record in past emergencies and the enormous obligations it has assumed in the present emergency should be convincing evidence of its entire loyalty to the United States.

MINERAL INDUSTRIES CONFERENCE, NOVEMBER 14 AND 15

Dedication of the Natural Resources Building

The Illinois Geological Survey, the Engineering Experiment Station of the University of Illinois, and the Illinois Mineral Industries Committee were hosts to the mineral industries organizations of Illinois and her sister states at the University of Illinois in Urbana-Champaign on November 14 and 15.

Completion of the Natural Resources Building on the campus of the University of Illinois will begin a new chapter in the development of the State. This structure, equipped with the most up-to-date facilities for research, with complete offices and laboratories, will make possible research investigations of the natural resources of Illinois that have not been undertaken heretofore for want of adequate facilities. Because it is dedicated to research and is unique among the states of this country, the State of Illinois wishes to express its justifiable pride in an appropriate manner.

An open-house gathering was held on November 14 for inspection of the new offices and laboratories of the Geological Survey. An all-mineral industries luncheon was followed by concurrent separate sessions on Coal, Oil, and Gas, Clay and Clay Products, Rock and Rock Products, and a symposium on the Geology of the Devonian System conducted jointly with the Department of Geology of the University of Illinois.

In honor of the dedication of the new building, the Industrial Minerals Division of the American Institute of Mining and Metallurgical Engineers held its fall meeting in Urbana, and its members participated in the sessions on Clay and Rock Products.

The dedication ceremonies of the Natural Resources Building took place on November 15 under the auspices of the Board of Natural Resources and Conservation and the University Board of Trustees. Isaiah Bowman, noted scientist, lecturer, and educator, and president of the Johns Hopkins University, gave the dedication address.

The Natural History Survey, which shares the building with the Geological Survey, sponsored conferences for its allied groups and joined in the dedication. State officials and delegates from leading universities and research institutions of the country and from various scientific and technical societies were present.

Following the dedication ceremonies, a reception was held in the foyer of the new building, and in the evening all of the groups joined in a dedication banquet.

The Natural Resources Building

Illinois Geological Survey Quarters

Dedicated to research, looking to the greatest possible development of the innate natural wealth of the State, this building has been constructed largely of Illinois materials.

Illinois face brick, made from Illinois shale in an Illinois plant, forms the exterior walls of the Georgian-style structure. Illinois white oak has been used for the doors and panel trim of offices and laboratories. A new interior architectural stone, produced recently in Illinois, forms the foyer walls. This will be a permanent exhibit, planned especially for the inspection of architects. The terra cotta that lines the walls of the laboratories was manufactured in Illinois, as well as the hollow tile used for interior walls and partitions. The sand in the masonry mortar and wall plaster and the aggregate for the concrete-foundation walls, structural columns, and floors are products of the rich and varied natural resources of Illinois.

Rising as a prominent feature of the south campus of the University of Illinois, the Natural Resources Building fits naturally into the campus panorama and conforms in style with other Georgian buildings nearby.

Its interior is planned so as to utilize fully and efficiently every cubic foot of space. The first floor, with its lobby, exhibit insets, and administrative offices, receives with dignity the interested citizen, investor, or technologist, who comes for service and information regarding the natural resources of the State and the products derived from them.

The other three floors are given over almost entirely to offices and laboratories. The piping for water, steam, compressed air, gas, and vacuum services is exposed and therefore is readily accessible for tapping or for making any changes that may be necessary to meet a flexible research program and, equally important, to permit repair and maintenance of service lines without destruction of walls and ceilings. The large chimneys, a characteristic but usually nonfunctional feature of Georgian architecture, are fully utilized in this building, because they serve as flue outlets for the numerous chemical hoods in the laboratories throughout the building. Electric current of various voltages to meet any possible research needs is available from scores of outlets.

Nine separate laboratories are to be devoted especially to the study of coal, supplemented by an X-ray laboratory, a spectrographic laboratory, a coal grinding room, a machine shop for making special research equipment that cannot be purchased, a small chemists' shop for glass-blowing and the assembly of chemical apparatus, a technical files room, where mine and drilling data are kept, a library, and an office of mineral economics.

Coal Research

Fundamental research on the botanical constitution of Illinois coal and applied research to utilize the information thus gained are to be carried out in laboratories on the second floor. It can now be said that the Illinois Geological Survey is literally "tearing coal apart" and determining the identity and characteristics of the original plant substances of which the different coal components are made. The mineralogy of the inert materials in coal is also to be thoroughly investigated. A better and more complete understanding of coal will result from these studies, leading to the devising of preparation methods that will improve stoker fuel, coal for domestic coke, and coal briquettes. Important groundwork is also being laid for researches dealing with the gasification of coal, the liquefaction of coal to make motor fuels, and the chemical use of coal fractions.

All chemical research on coal is to be carried out in the laboratories of the Geochemical Section on the third floor. Standard analyses will be made in the analytical laboratories, and special problems of analysis will be handled in the analytical research laboratory.

To give attention to research on the physical properties of coal, a branch of research that heretofore has been only partially presented, physics laboratories have been equipped on the fourth floor. This program of physical research will be fundamental to a better understanding of coal and its possibilities and will also include research on coal briquetting and combustion.

Researches and experimentation on a scale too large for the laboratories of the Natural Resources Building will be conducted in the new Geological Survey Applied Research Laboratory located near the new power plant of the University. The new briquetting machine, now nearing completion in the plant of the J. P. Devine Manufacturing Company at Mt. Vernon, Illinois, will be located in this building. After the installation of the machine and after whatever modifications may be necessary, it will be used to demonstrate the manufacture of smokeless briquettes. Special combustion studies will also be carried on in this building.

Other Minerals Research

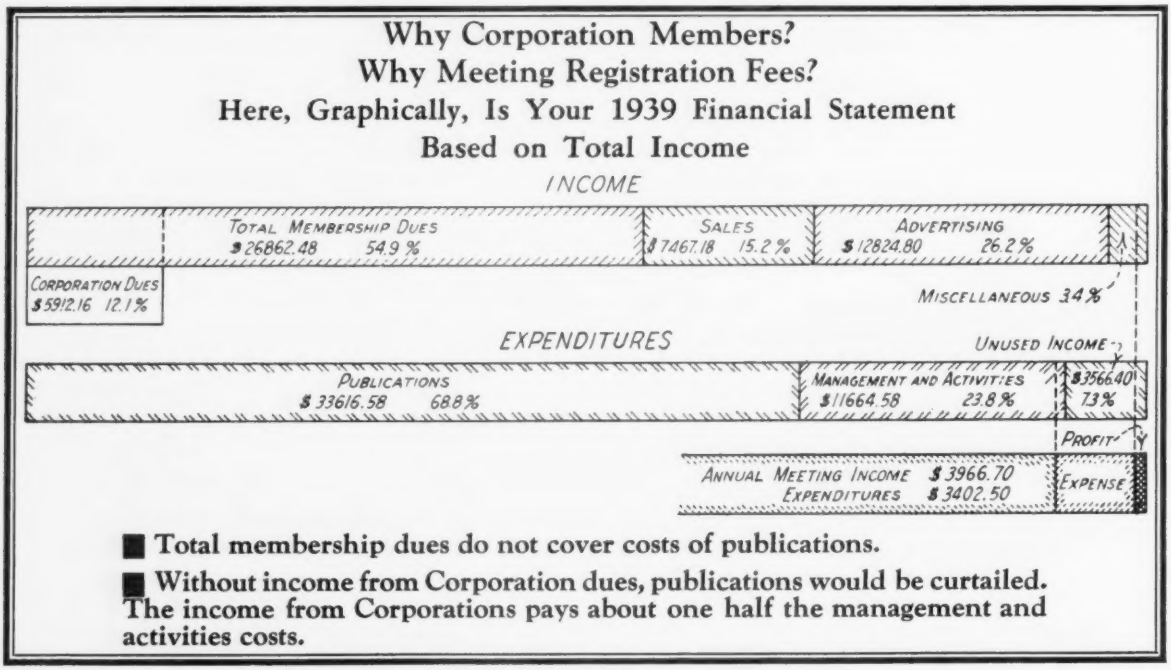
With respect to oil, gas, and water resources, ample quarters are provided for the filing of well logs, the study of cuttings and cores, the drafting of log-strips and maps, preparation of reports, and the handling of interviews and correspondence. Laboratories are fully equipped for the analysis of oil, gas, and brines and for the determination of the porosity, permeability, and saturation of oil sands.

Clay Research

The study of the State's resources of industrial minerals involves separate investigations of many types of clays, shales, limestones, dolomites, sandstones, silica sand, tripoli, fluorspar, molding sand, fuller's earth, and other deposits. The expectation of finding new and improved uses for these materials and the need for full investigation of the economics of their distribution and marketing were important items that had to be considered in planning special laboratories, sample files, preparation rooms, and offices. Among the ten laboratories to be devoted to this work alone is a special microscopic laboratory for the study of the physical and mineralogical composition of clays and shales and laboratories in physical chemistry and fluorine research. This equipment together with X-ray and spectrographic apparatus and other special physics and chemistry facilities that have been provided will see considerable service in the industrial mineral research program.

The Department of Ceramic Engineering of the University, a sister research agency in ceramic materials, already has adequate equipment in kilns, furnaces, and other apparatus, and these have not been duplicated.

Improved quarters have also been provided for the divisions of paleontology and stratigraphy, areal and engineering geology, petroleum geology, subsurface geology, mineral economics, educational extension, and publications and records. That portion of the building occupied by the State Natural History Survey is planned with equal efficiency for the most modern research on the biologic resources of the State.



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Norton Co. (*Alundum-Crystolon*)

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

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Ceramic Color & Chemical Mfg. Co.
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Harshaw Chemical Co.
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Pacific Coast Borax Co.
The Vitro Mfg. Co.

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Norton Co.
The Vitro Mfg. Co.

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Harshaw Chemical Co.
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Denver Fire Clay Co.
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FORTY-THIRD ANNUAL MEETING OF THE AMERICAN CERAMIC SOCIETY

BALTIMORE, MARYLAND, MARCH 30 to APRIL 5, 1941

The Star Spangled Banner

Fort McHenry, with its antiquated guns frowning over Baltimore harbor, is one of the nation's foremost historic shrines—the birthplace of the Star Spangled Banner. Our National Anthem was written in Baltimore on the 14th of September, 1814, by Francis Scott Key, a native of Frederick, Maryland.

After the burning of Washington, the British fleet, comprising sixteen bomb and rocket vessels convoying 5,000 land troops, sailed up the Chesapeake Bay to capture the city of Baltimore. The British soldiers debarked at North Point and advanced on the city, while the warships prepared to attack Fort McHenry. On the evening of September 12, Key went aboard the British flagship to arrange for the release of Dr. William Beanes, a native of Maryland, who had been arrested by the British. Because of the impending battle, Key was returned to his flag-of-truce ship under a marine guard and forced to remain immediately in rear of the fleet.

Shot and shell rained upon McHenry's ramparts throughout the next day and night. Toward morning of the fourteenth, Key's anxiety was multiplied a hundred-fold when, by reason of its ineffective range, the Fort ceased fire, and he could no longer hear the reassuring roar of its guns.

"At Dawn's Early Light!"

Shortly before daybreak, the British guns became silent, and through the smoke-thickened mist of dawn, Key kept a constant vigil in the direction of the battle-scarred Fort. Imagine his elation when he saw dimly but surely the Stars and Stripes waving in proud defiance above the Fort! In the exultation of that sublime moment and aflame with patriotic fervor, Key jotted down on the back of a letter a hasty outline of that stirring tribute to the defenders of Baltimore—an immortal panegyric to the flag of his native land.

Repulsed on land as well as on water, the British troops reembarked and the fleet sailed away. Key returned to Baltimore, where his poem was received with popular acclaim. Hundreds of copies were printed and the words were sung to the tune of "Anacreon in Heaven." The popularity of the song soon became nation-wide, and it was generally accepted as our national anthem. However, it was not until 1931 that Congress gave official recognition to the Star Spangled Banner.

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Norton Co.
Potters Supply Co.

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Lancaster Iron Works, Inc.
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Bethlehem Steel Co.

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The Vitro Mfg. Co.

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The Hommel, O., Co., Inc.
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Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

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Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

French Flint
Maxson, Elwyn L.
Paper Makers Importing Co.

Frit
Ceramic Color & Chemical Mfg. Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Frosting Mixtures
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Fuel Oil Systems and Control, Stokers
Bethlehem Steel Co.
Frazier-Simplex, Inc.

Furnaces
Carborundum Co. (*Carboradiant*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Swindell-Dressler Corp.

Furnaces, Enameling
Swindell-Dressler Corp.

Glass Bending Ovens, Glass Decorating Machines
Frazier-Simplex, Inc.

Glass Equipment
Hartford-Empire Co.
Lancaster Iron Works, Inc.

Glass Melting Tanks and Furnaces
Frazier-Simplex, Inc.

Glass Sand
Great Lakes Foundry Sand Co.

Glass Thickness Gauge
Bausch & Lomb Optical Co.

Glaze and Body Spar
Ceramic Color & Chemical Mfg. Co.
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

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The Vitro Mfg. Co.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.

Goggles
The Hommel, O., Co., Inc.
Willson Products, Inc.

Gold
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Gold Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Granulators
Lancaster Iron Works, Inc.

Grinding Wheels
Carborundum Co. (*Carborundum and Aloxite*)
Chicago Vitreous Enamel Product Co.
Norton Co. (*Alundum-Crystolon*)

Hearths
Carborundum Co. (*Carbofrax* heat treating)
Corhart Refractories Co.
Green, A. P., Fire Brick Co.
Norton Co. (*Crystolon*)

Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.

Hose (Air and Fluid)
The DeVilbiss Co.

Hydrofluoric Acid
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Iron Chromite
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.

Iron (Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Iron Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Kaolin
Ceramic Color & Chemical Mfg. Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Kilns, China (Decorating)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Swindell-Dressler Corp.

Kilns-(Electric, Circular, Tunnel)
Swindell-Dressler Corp.

Kiln Furniture (Silicon Carbide, Semi-Silicon carbide) (Refractory)
Louthan Mfg. Co.

Kyanite
Celo Mines, Inc.

Kryolith (see Cryolite)
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Laboratory Ware
Norton Co.

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Carborundum Co.

Lehrs
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehr Loaders
Frazier-Simplex, Inc.

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Corhart Refractories Co.
Denver Fire Clay Co.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.
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Lithium Carbonate
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Lithium Minerals
Foote Mineral Co.

Loaders (Bucket)
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Magnesia (Fused)
Norton Co.

Magnesia (Sintered, Calcined)
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Magnesite
Ceramic Color & Chemical Mfg. Co.
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Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel, O., Co., Inc.

Magnesium Carbonate
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Cornart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Masks (Breathing)
The DeVilbiss Co.
Drakenfeld, B. F., & Co.
Willson Products, Inc.

Metals (Porcelain Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

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Spencer Lens Co.

Microscopes (Stereoscopic)
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Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

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National Engineering Co.

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National Engineering Co.

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National Engineering Co.

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Frazier-Simplex, Inc.
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Norton Co.

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National Engineering Co.

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Denver Fire Clay Co.
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Pennsylvania Salt Mfg. Co.

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Harshaw Chemical Co.
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Great Lakes Foundry Sand Co.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

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Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Nitre
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

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The Hommel, O., Co., Inc.
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Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

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Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
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Louthan Mfg. Co.
Potters Supply Co.

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Louthan Mfg. Co.

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United Clay Mines Corp.

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Porcelain Enamel and Mfg. Co.
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Accurate Pyrometric Cone Co.
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Spencer Lens Co.

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Corhart Refractories Co.
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
Norton Co.

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Corhart Refractories Co.
Denver Fire Clay Co.
Louthan Mfg. Co.
Norton Co.
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Thomas Alabama Kaolin Co.

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Willson Products, Inc.

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Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.
Willson Products, Inc.

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Norton Co.
Potters Supply Co.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

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Willson Products, Inc.

Sandblast Sand
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The Vitro Mfg. Co.

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The Vitro Mfg. Co.

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Bethlehem Steel Co.

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Edgar Plastic Kaolin Co.
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Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

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Carborundum Co.
Norton Co.

Silicon Carbide Firesand
Carborundum Co.

Sillimanite Refractories
Denver Fire Clay Co.

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Carborundum Co.
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Norton Co.

Soda Ash
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Sodium Antimonate
Ceramic Color & Chemical Mfg. Co.
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Sodium Fluoride
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
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The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Sodium Metasilicate
Harshaw Chemical Co.

Sodium Nitrite
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Sodium Silica Fluoride
Ceramic Color & Chemical Mfg. Co.
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The Hommel, O., Co., Inc.

Sodium Uranate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Soot Blowers
Frazier-Simplex, Inc.

Special Machines
Frazier-Simplex, Inc.

Spar
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Spray Booths
The DeVilbiss Co.
The Hommel, O., Co., Inc.

Spraying Equipment
The DeVilbiss Co.
The Hommel, O., Co., Inc.

Spurs
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Potters Supply Co.

Stacks
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Bethlehem Steel Co.
Lancaster Iron Works, Inc.

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Louthan Mfg. Co.
Potters Supply Co.

Sulfuric Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Talc
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Paper Makers Importing Co.

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Tile (Muffle)
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Norton Co.

Tile Setter Pins
Louthan Mfg. Co.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
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Green, A. P., Fire Brick Co.
Norton Co.
Thomas Alabama Kaolin Co.

Tile (Wall)
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Thomas Alabama Kaolin Co.

Tin Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Titanium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Titanium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Trisodium Phosphate
Harshaw Chemical Co.

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Lancaster Iron Works, Inc.

Tubes (Insulating)
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Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
McDanel Refractory Porcelain Co.
Norton Co.

Tubes (Pyrometer)
Carborundum Co.
Denver Fire Clay Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.

Uranium Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Uranium Oxide (Yellow-Orange-Black)
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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Water Softening Plants
Frazier-Simplex, Inc.

Wet Enamel
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Whiting
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Winding Drums
Lancaster Iron Works, Inc.

Zinc Oxide
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

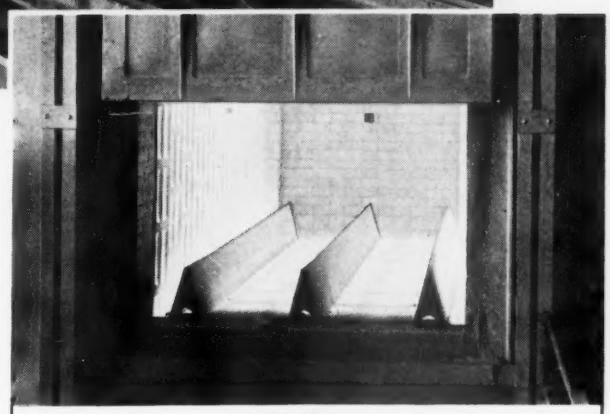
Zircon
Edgar Plastic Kaolin Co.
Foote Mineral Co.
The Hommel, O., Co., Inc.

Zirconia
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Zirconium Oxide
Foote Mineral Co.
The Hommel, O., Co., Inc.
Titanium Alloy Mfg. Co.

Zirkite (Natural ZrO_2)
Foote Mineral Co.

● The muffle is of "Alfrax," the Aluminum Oxide Refractory by Carborundum.
The recuperator is equipped with tubes of "Carbofrax," the Carborundum Brand Silicon Carbide Refractory.
The furnace is by Whipple Furnace Company of Chicago.
The installation is in the plant of a mid-west company and the work is enameling steel stove parts.
Records on this job show that the extremely thin plate "Alfrax" muffle provides unusually rapid and uniform heat conductivity, thus assuring a marked fuel economy—plus a chemical stability which makes certain long, economical muffle life.
The recuperator equipped with "Carbofrax" tubes furnishes air for drying, thus eliminating a heavy fuel bill for drying ware.
And to top it all off, the furnace performance is at such high efficiency as to produce an extremely high grade of enameled ware—and more of it.
May we suggest that Carborundum Engineering Service can help you to equally productive results?



REFRACTORY CARBORUNDUM PRODUCTS

THE CARBORUNDUM COMPANY
REG. U. S. PAT. OFF.

Refractory Division, Perth Amboy, N. J.

District Sales Branches: Chicago, Philadelphia, Detroit, Cleveland, Boston, Pittsburgh. Distributors: McConnell Sales and Engineering Corporation, Birmingham, Ala.; Christy Firebrick Company, St. Louis, Mo.; Harrison & Company, Salt Lake City, Utah; Pacific Abrasive Supply Company, Los Angeles, San Francisco, Calif.; Denver Fire Clay Company, El Paso, Texas; Smith-Sharpe Company, Minneapolis, Minn.

{Carborundum, Carbofrax and Alfrax are registered trade-marks of and indicate manufacture by The Carborundum Company}

EXECUTIVE OFFICE EXHIBITS

One of five enclosed cases of exhibits in the Executive Offices of The American Ceramic Society.

Franciscan pottery of the Gladding, McBean & Company.

Vernonware of the Vernon Kilns.

H. C. SPINKS CLAY COMPANY

Miners and Shippers of

BALL, SAGGER AND WAD CLAY

NEWPORT, KY.

November 1, 1940

Mr. Pete Potter
Comfortable Sanitary Pottery Mfg. Co.
Pottsville, U. S. A.

Dear Pete:

No use me telling you to—I know you are going to vote right. No, I ain't going to Gallup into a prediction on the election.

Win, lose, or draw—we got to take it—keep faith in our country and keep on trying. Try as hard as you want to, Pete, you won't find better BALL CLAYS than CHAMPION & CHALLENGER and JERNIGAN.

Sincerely,

Dick Carothers

General Manager
H. C. SPINKS CLAY COMPANY

RBC:MLN

M and T TIN OXIDE

Brilliant . . . rich . . . snow-white . . . free of specks and discolorations . . . that's the kind of glaze you want, and that's the kind you will get consistently with M & T Tin Oxide.

Hundreds of important firms have standardized on the use of M & T Tin Oxide because it assures, at an advantageous price, the superior results they demand.

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